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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years not more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees	*Annual Dues*
Members	$ 3.00	$ 8.00
Juniors	1.00	3.00
Associates	10.00	25.00
Corporate Members	10.00	15.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

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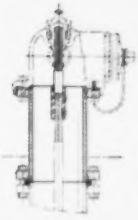

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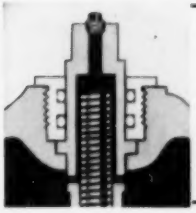

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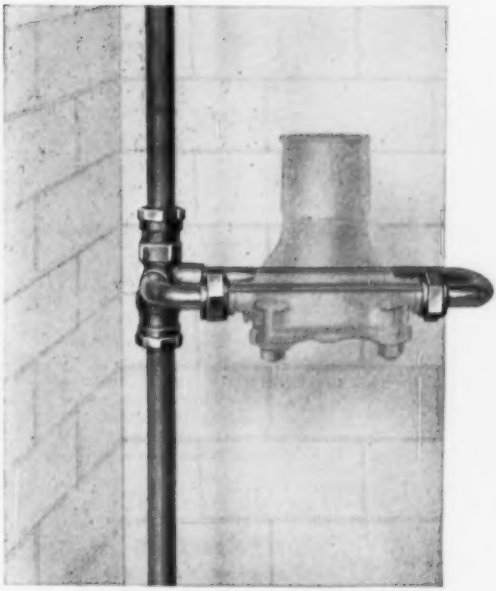

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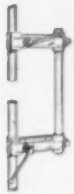
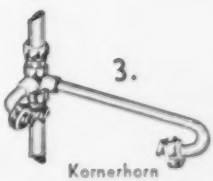


1. Cut supply line. Clamp not necessary but convenient

2. Add Connections



3. Kornerhorn in place

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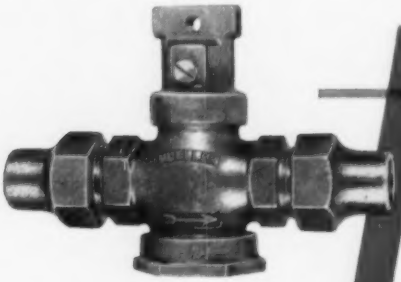

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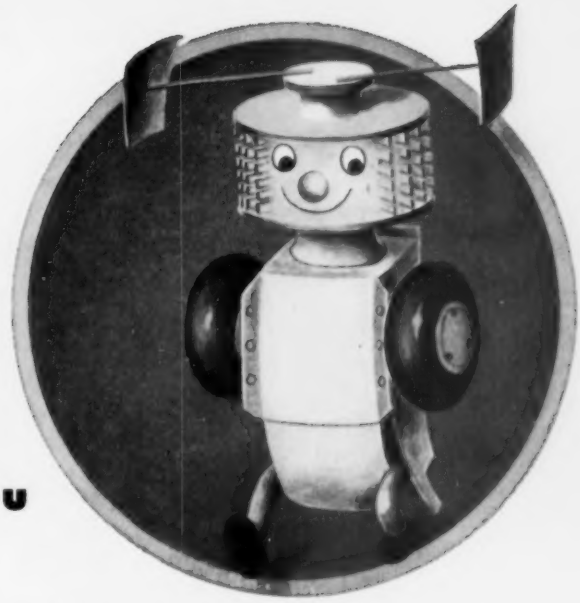

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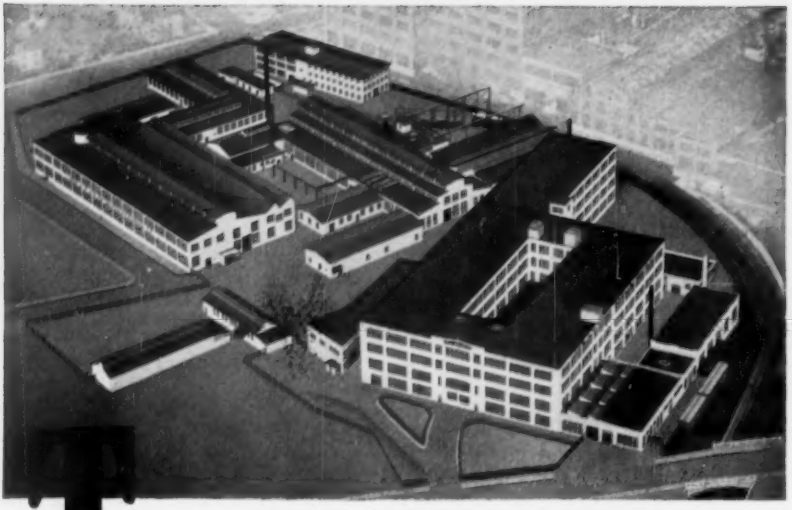

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produces, FIRE HYDRANTS A. W. W. A. Specification and High Pressure — Compression Type — Dry and Wet Barrel Types. GATE VALVES sizes 2" thru 66", Manual, Hydraulic Cylinder, Electric Motor Operated for Low, Medium and High Pressure Service. INSERTING VALVES sizes 4" thru 48" for inserting under pressure. TAPPING SLEEVE AND VALVES sizes 4" x 2" thru 60" x 48" for branch connections under pressure.

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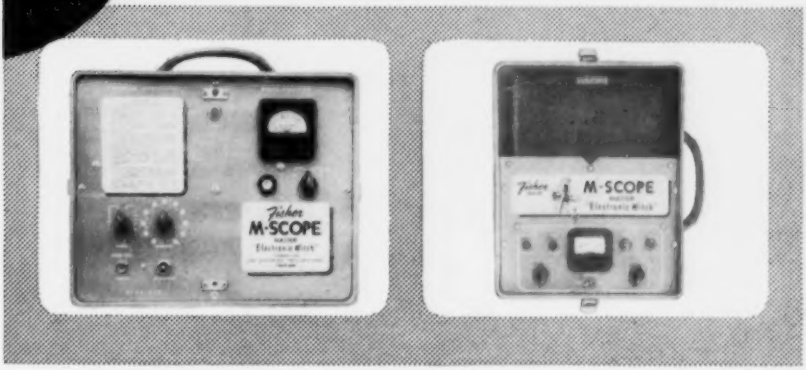
TIME-$AVING COMBINATION LEAK DETECTOR-PIPE LOCATOR



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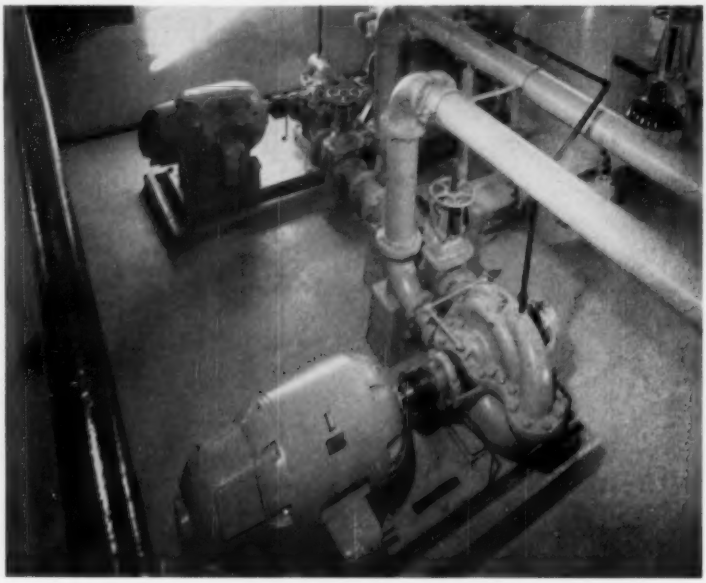

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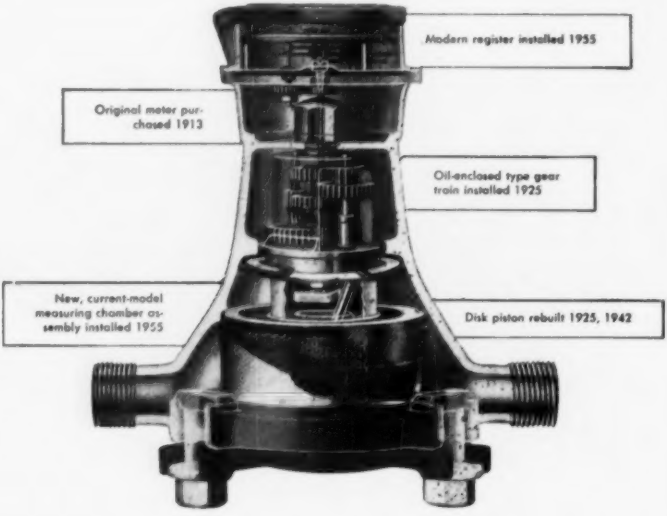
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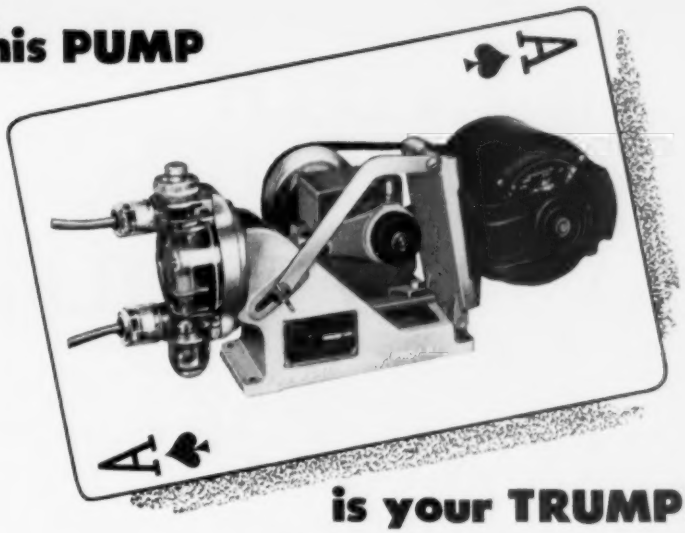

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Hotel Statler, Boston

SEPTEMBER 15-18, 1957

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New England Water Works Association
ORGANIZED 1882

VOL. LXXI JUNE, 1957 NO. 2

This Association, as a body, is not responsible for the statements or opinions of any individual.

ST. LAWRENCE POWER PROJECT

BY W. M. HALL*

[*Read September 17, 1956.*]

HISTORY

The large quantity of potential power in the St. Lawrence River between Lake Ontario and tidewater at Montreal, Canada, was well known long before the development of power was commenced. Likewise, the large quantity of potential power in the Niagara River between Lake Erie and Lake Ontario was well known long before any development materialized.

Navigation possibilities were similarly well known for an even much longer period of time. There was navigation on the St. Lawrence River in the 18th century, before the American Revolution. The objective has long been and still is:—a seaway suitable for ocean-going ships to navigate from Montreal Harbor to all ports on the Great Lakes.

When the use of electricity began to grow, shortly before the year 1900, engineers promptly realized the power possibilities of the St. Lawrence River. This tremendous stream originates at the outlet of Lake Ontario, draining the largest body of fresh water in the world —the five Great Lakes. These lakes form an enormous natural regulating reservoir, which smooths out the variations of flow from tributary streams within the watershed and tends to equalize the out-flow from season to season. Below Lake Ontario the river drops about 92 ft in less than 50 miles throughout the International Rapids along the United States-Canadian border. The large steady flow combines with this fall to create an unusual natural opportunity for power production.

A partial hydroelectric development of Niagara Falls took place

*President, Chas. T. Main, Inc., 80 Federal St., Boston, Mass.

in about 1895 on the American shore. Subsequently, Canadian hydroelectric projects have been carried out and the Canadian development of the Niagara Falls is now in its final stages.

The rapids in the lower portion of the St. Lawrence River, lying entirely within Canada, have long since been developed with major power facilities. Canadians have also constructed a 14-foot navigation draft facility through the International Rapids of the St. Lawrence River by a system of canals and locks.

Studies, reports and legislation have been under consideration for many years for the development of hydroelectric power in the international section of the St. Lawrence River. As long ago as 1909 the Boundary Waters Treaty between the United States and Canada specified the uses to be made of international waters and established the International Joint Commission.

Canadian legislation and Presidential order designated, respectively, the Hydro-Electric Power Commission of Ontario and the Power Authority of the State of New York as instrumentalities of each nation responsible for construction and operation of the St. Lawrence Power Project. A 50-year license for the construction and operation of the project by the Power Authority was issued by the Federal Power Commission in 1953. In the fall of 1953 the Power Authority engaged Sanderson & Porter of New York and Uhl, Hall & Rich of Boston, a joint venture, to make an engineering report and estimate of cost of the project suitable for financing and budget control. This assignment was completed in August, 1954.

As of September 1, 1954, Uhl, Hall & Rich was engaged by the Power Authority to design, supervise all field investigations, manage the construction, and carry out initial operation of the St. Lawrence Power Project.

Uhl, Hall & Rich is an affiliate of Chas. T. Main, Inc. The seven directors of Chas. T. Main, Inc., are all partners of Uhl, Hall & Rich, and all seven partners are registered licensed engineers in the State of New York.

Definition of Project

There is much uncertainty in the minds of many business and professional men, including well-informed engineers, as to exactly what the St. Lawrence Power Project really is. This is partly due to

the unusual publicity given to one and then another of several non-related projects, partly due to the former long-time efforts to secure authority for a combined power and seaway project, and partly due to a possible combination of Niagara and St. Lawrence hydroelectric powers.

The St. Lawrence Power Project is a completely separate undertaking from the seaway project. The St. Lawrence Seaway Project has been authorized and financed, is being carried out by the United States and Canadian Governments, and will continue to be a separate undertaking.

Likewise, the St. Lawrence Power Project is an entirely separate undertaking from the Niagara Power Project. There is no doubt but that the Niagara Project will eventually develop all of the available power at Niagara Falls, but there has been no authorization for the construction and operation of this project as yet.

Financing

The construction cost excluding power-plant equipment is borne equally by the Power Authority of the State of New York and Hydro-Electric Power Commission of Ontario. The Power Authority and Ontario Hydro bear their own cost of power and transmission plant equipment, working capital, interest during construction, and other miscellaneous expense and credits.

The total cost is estimated to be about $560 million. The estimate of the Power Authority share of the equally divided cost is $235 million, power and transmission plant about $50 million, non-construction items about $50 million net, making the total Power Authority requirement $335 million.

The Power Authority borrowed $40 million in July, 1954, to start construction in the field and the procurement of plant equipment. This was on a short-term basis. In December, 1954, the Revenue Bond Issue of the entire Power Authority requirement of $335 million completed the financing of their portion of the project.

River Flow and Distribution

Above the International Rapids section, the watershed of the St. Lawrence River covers an area of about 300,000 sq mi between

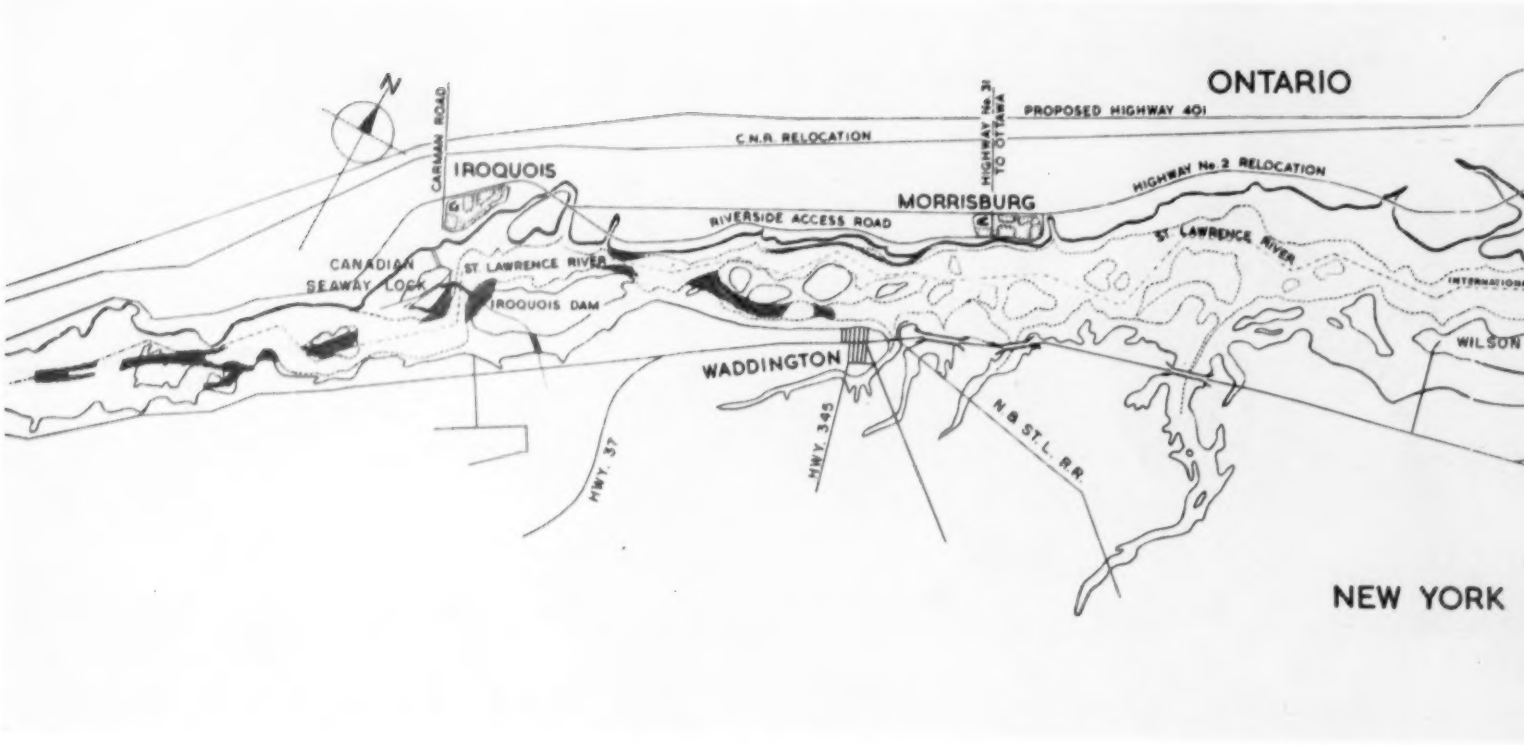
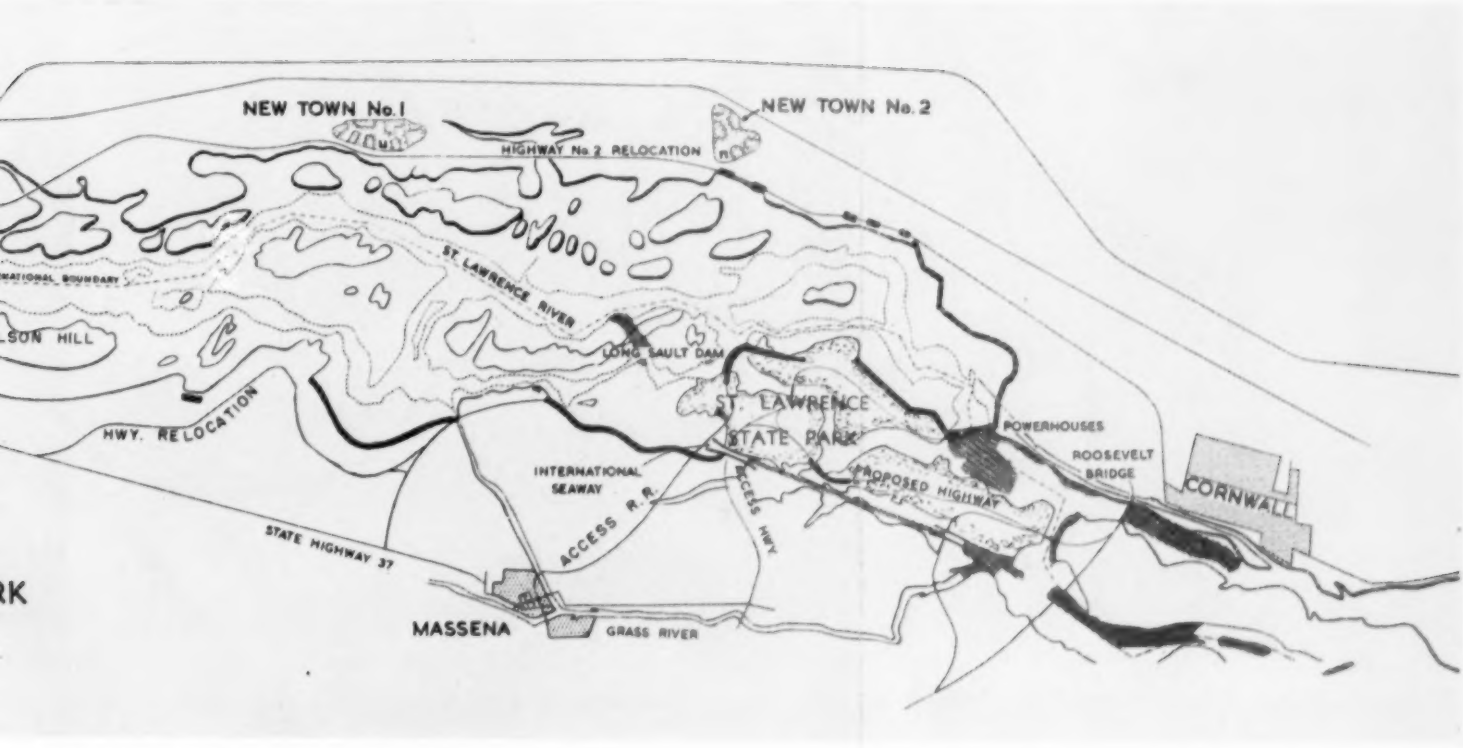


FIG. 1.—GENERAL LOCATION PLAN OF ST



OF ST. LAWRENCE POWER PROJECT.

the United States and Canada, including the five Great Lakes which constitute nearly one-third of the entire drainage area. Annual rainfall over the area averages 31 in., about one-third of which runs off to the river. Lake levels and out-flow from Lake Ontario have been recorded for almost a century.

The St. Lawrence is one of the world's large rivers. Its historical average annual discharge at the outlet of Lake Ontario is 236,000 cfs, which is exceeded by only a few rivers on the North American continent. Its primary advantage from the standpoint of hydroelectric power production, however, is not its total discharge but the uniformity of its flow year by year and season by season.

The maximum flow on record is a little more than twice the record minimum flow. For example, other streams of comparable size vary much more widely. The Columbia River has a ratio of 35 to 1; the Mississippi River 25 to 1; and the Ottawa, which joins the St. Lawrence below the project, 31 to 1.

The river flow useful for power will be divided equally between the Power Authority and Ontario Hydro. The capacity of the Power Authority section of the power plant equals the capacity of the Ontario Hydro section of the power plant.

Project Features

The project consists of two major dams, the powerhouse intake structure, power and transmission plant equipment, extensive river channel works, dikes and miscellaneous construction. It is necessary to relocate highways, railroads, navigation facilities, as well as homes and towns within the forebay pool area. Access by railroad and highways and construction camps required extensive work of a temporary nature.

Iroquois Dam

The Iroquois Dam is located a short distance downstream from Ogdensburg, N. Y., opposite the town of Iroquois, Canada (see Fig. 1). It is a buttressed, gravity concrete structure, consisting principally of a series of piers and sluiceways. There will be 40 openings between piers and these are controlled by 32 two-section, fixed-roller,

vertical lift gates and 8 single-section gates of the same type, all operated by two 225-ton-capacity, traveling gantry cranes.

The function of the Iroquois Dam is to act as a flow control and regulator, to replace the natural rock ledge near Galop's Island upstream from the dam, being removed to provide the necessary channel for navigation. The dam will regulate the out-flow from Lake Ontario and restrict to the practicable minimum any variations in lake level that would adversely affect the physical properties along the lake shore. It will also expedite the formation of a very desirable, solid ice sheet on the upper river during the winter season. From the standpoint of power-plant operation, the dam will permit the essential operation of daily pondage variations without variations in the level of Lake Ontario.

Long Sault Dam

The Long Sault Dam extends from the American shore to the head of Barnhart Island and closes the south river channel. This dam is entirely in United States territory and is located slightly northeast of the town of Massena, N. Y.

The Long Sault Dam is a conventional, gated, spillway, concrete gravity structure, curved in plan to conform with the natural location of the most favorable bedrock foundation. The maximum height of the dam above foundation is 145 ft. The dam will raise the water level about 90 ft above the river bottom. Vertical lift gates will be provided to discharge any river flows which are not passed through the power plant.

There will be 30 gates, each 50 ft wide. The gates will pass the maximum known January river flow of 220,000 cfs at the minimum pool elevation, which is 11 ft lower than the ultimate pool level.

Eighteen of the gates, in the center of the spillway and opposite the deepest part of the river channel, are divided horizontally into two sections, so that floe ice may be skimmed over the lower gate section. These 18 gates will have fixed individual hoists. The remaining 12 gates will be operated by either of two traveling gantry cranes. Air bubblers and electric heaters will be provided for all gates, due to the severe icing conditions during the winter season.

Barnhart Island Powerhouse

All of the power generated by the St. Lawrence Power Project will be produced at the Barnhart Island power plant, which spans the north channel of the river at the lower end of Barnhart Island, with one-half the plant located in the United States and the other half in Canada. The American section of the powerhouse intake structure alone is the largest single feature of the project. This structure, together with the Long Sault Dam and attached dikes, controls all of the channels of the river in the vicinity of Barnhart Island and creates the pool for the development of power. The total installation of the combined American and Canadian sections of the plant has a capacity of 1,800,000 kw, developed by 32 generating units.

The powerhouse intake structure actually serves as a concrete dam about 3,200 ft long, which spans the channel in a straight line at right angles to the direction of natural water flow. The deck of the intake structure will be 162 ft above the low point of the draft tubes.

Flat rolling hatches in the deck above each generator will permit the removal of any part of the unit by an overhead, outdoor gantry crane, traversing the length of the powerhouse as needed for major repairs. The traveling crane will carry a housing of sufficient size to enclose the part during its removal from the unit and transportation to maintenance bays. This housing will be heated when in use during the winter season. The maintenance bays will be enclosed by superstructures of sufficient size to admit a gantry crane and its load.

Intake gates are provided for each turbine and are operated by individual fixed hoists. Sectional steel stoplogs will operate in separate slots to provide for emergency closure of the intake openings. Traveling gantry cranes will be located on the intake for the handling of intake gates, stoplogs, trash-rack sections, and other miscellaneous requirements.

The hydraulic turbines are of the vertical-shaft type with fixed-blade propeller runners. The turbines are designed to develop 71,000 hp each under 81 ft of head at the gate opening offering the best efficiency. The ultimate operating head will vary from 77 ft to about 88 ft, and the maximum capacity of the turbine under full gate operation will be 88,000 hp. About 8,400 cfs of water will pass

through each turbine under normal conditions; the discharge will increase to nearly 10,000 cfs under extreme conditions.

The directly connected generators are rated 57,000 kilowatts capacity and are capable of carrying a continuous overload of 15%, or more than 65,000 kilowatts.

Power will be generated at 13,800 volts. Step-up power transformers will be located as near as convenient to the generators on a downstream platform above the draft tubes. A bank of three single-phase transformers will be connected to four generating units, thus requiring four banks of transformers in the American section of the power plant alone.

On the American side, two banks of transformers will operate at 230,000 volts on the high-tension side, and the two remaining banks will operate at 115,000 volts on the high-tension side. Cables will connect the transformer banks to the switchyard, located as near as convenient to the south end of the powerhouse. The cable installation will be of the high-pressure, oil-filled pipe type. The generating equipment, transformer banks and switching equipment located within the American section of the power plant will be controlled from a central point near the south end of the powerhouse structure.

The Canadian generating units and transformer banks will be of these same capacities, and any variations will be confined to voltages, switchyard arrangements and other details due to local operating needs on the Canadian transmission system.

Earth Dikes

The pool behind the Long Sault Dam and the powerhouse will rise to elevations higher than those of the surrounding areas of land and improvements in a number of locations. Earth embankments or dikes are being constructed to confine the pool at these locations. Altogether there will be about 14 miles of these dikes, having a maximum height of about 40 ft and located both in the United States and in Canada.

Embankment material is glacial till earth obtained from areas adjacent to the dike sites. The central portion of the dike sections has impervious cores, supported by similar material compacted to a lesser extent and containing stones and boulders. Sand-and-gravel and

also rock sections will be provided in the downstream toes of the embankment to facilitate drainage and insure stability. The upstream slopes are protected against wave action by heavy rock riprap, placed upon a filter blanket of sand and gravel. The downstream slopes will be seeded to grass where possible.

The foundation material at the dike sites is largely glacial till with some areas of soft marine clay. The dikes rest upon glacial till foundation insofar as possible.

River Channel Improvements

Long sections of channel excavations are being carried out and will be of real value to navigation, conserve power head and facilitate operation of the power plant during the winter, by limiting the river velocities so that a solid sheet of ice may form over the forebay area, thus precluding ice jams in the pool. Both wet and dry excavation, as well as both earth and rock excavation, are required in three areas —upstream from the Iroquois Dam, downstream from the Iroquois Dam, and below the Barnhart Island powerhouse.

The unusual design calculations for the channel improvements have been supplemented to a major degree by extensive model tests, which have been carried out in the hydraulic laboratory of Ontario Hydro at Toronto, Canada.

Other Features

The remaining features consist primarily of relocations of features now located within the areas of the power pool. These consist of highways, railroads, portions of villages, individual homes, cemeteries, and other items.

A new power intake is being provided, to permit the operation of a low-head power plant until the Barnhart Island power plant is ready for operation.

Construction Schedule

The actual construction work on the project commenced in the summer of 1954, and several of the generating units are expected to be in operation by the fall of 1958, with all of the units in operation by the end of 1959. In order to accomplish this, nearly all of the construction work must be completed in 1958, in order to raise the water

level upstream from the powerhouse prior to the scheduled operation of the plant. Schedules were carefully worked out in detail, from the acquisition of land to permit construction to start, to the final completion of the construction of the project.

In order to proceed promptly with the work, numerous small construction contracts were awarded in 1954 without waiting for contract plans and specifications for the large major features. These contracts include a first-stage cofferdam for the Long Sault spillway dam, complete cofferdams for the Barnhart Island power plant, a pontoon one-season bridge to Barnhart Island, a permanent bridge also to Barnhart Island, access roads and railroads, administration buildings, construction power lines, and other items.

Construction contracts for the large major features of the project were awarded last spring. There are separate large contracts for the American and Canadian sections of the power plant, and other large contracts are for the construction of the Long Sault Dam, for the Iroquois Dam, and for several sections of river-channel dredging. Numerous other features are contracted for separately, such as earth dikes, highway relocations, rehabilitation, and other miscellaneous work.

Large items of permanent equipment are contracted for separately. These include hydraulic turbines, generators, transformers, cranes, and other items. These contracts were awarded last spring. Minor items of permanent equipment are being furnished by the various construction contractors involved.

Project Construction

Uhl, Hall & Rich has a large field organization to carry out the necessary field investigations, furnish construction management for the numerous contracts, and carry out initial operation of the plant. This organization is supplemented by service contracts with surveying and drilling companies and services furnished by several New York State departments for special reasons.

In addition to the usual needs, noted primarily for the size of the undertaking, a major coordination service is required. This relates to corresponding activity on the part of Ontario Hydro, the nearby American seaway operations, the Canadian Department of Transport, which is now operating the present 14-foot navigation channel to a

lesser extent, and also to the authorized agencies of the United States and Canadian governments.

New access roads and a railroad extension were required for the construction of the larger features of the project. The principal access road to Barnhart Island intersects the line of the United States section of the seaway and will eventually underpass the seaway. A parallel access road will eventually be abandoned before the seaway is put into operation. A pontoon bridge from the south shore of the river to Barnhart Island gave access last year, prior to the completion of a permanent bridge. This permanent bridge now provides access to Barnhart Island for the remainder of the construction period and thereafter.

During the construction period all of the flow of the river is diverted from the north side of Barnhart Island, through the Long Sault Dam site south of Barnhart Island. This permits the cofferdam for the powerhouse and its intake to be constructed at one time, thus permitting the construction work in this area to be carried on continuously until completion.

The Long Sault Dam is being constructed in two stages. The first section of the dam will be located inside of a cofferdam, which extends out from the American shore to about the middle of the river. As the work inside of this cofferdam nears completion, a second cofferdam will be constructed, extending from near the middle of the river to Barnhart Island. Upon removal of the first-stage cofferdam, the river will flow entirely through openings left in the first section of the dam. Large excavations are required on the island upstream from the dam, to divert water during the first cofferdam stage, and other large excavations are required for use during the second stage of the construction.

Iroquois Dam is being constructed in the same manner as the Long Sault Dam, and there will be two stages of cofferdam. In this case, the first section of the permanent dam will be largely constructed outside of the present river channel and thus require only a minor structure for the first-stage cofferdam.

The control of the river must be carried out during all cofferdam stages and the raising of the pool without detrimental effect to the elevation of Lake Ontario upstream from the project and without

detrimental effect to the elevation of Montreal Harbor downstream from the project. The disposal of the large quantity of material excavated from the channel is an important problem. The river channel and seaway excavations are closely related to the earth-embankment work on the dikes, especially as much excavated material can be used in embankments when the hauling distances are reasonable.

The international boundary intersects the center of the powerhouse and also intersects the Iroquois Dam and numerous sections of the channel excavation lying on both sides of the boundary. The location of the international boundary has a definite effect on the construction of the project in many respects. The physical work is divided as equally as possible between the Power Authority of the State of New York and the Hydro-Electric Power Commission of Ontario.

The field organization of Uhl, Hall & Rich operates from an administrative area near the American shore of the river and the permanent access bridge to Barnhart Island. Ontario Hydro operates from an area north of the Canadian shore and the power plant. Both groups have a number of sub-offices located at important points in the area from Iroquois Dam to the power plant.

APPLICATION AND OPERATION OF THE SUBMERSIBLE MOTOR AND PUMP

BY JOHN E. HAWKS*

[*Read September 18, 1956.*]

The pumping of water from underground supplies has long been the only reliable source in many areas of the world. Equipment for pumping this water to the surface has continued to improve as pumping requirements have increased. The deep-well turbine pump in the past has very satisfactorily met the needs for agriculture, industry and municipal usage, and to a very large extent is responsible for our continued growth and resulting high standard of living.

The continued expansion and need for more water in agriculture and industry, and for municipal use, in many cases, is beginning to impose pumping conditions that are not compatible with present deep-well turbine pump construction, mainly due to lineshaft limitations. Let us all compare the ease and convenience of transmitting electrical power versus the limitations and inconvenience of transmitting mechanical power. The deep-well lineshaft turbine pump with an electric drive converts electrical power to mechanical power at the surface. It is then necessary awkwardly to transmit this mechanical power through the lineshaft to the pumping element, in order to accomplish the desirable conversion to hydraulic power. It is readily realized that the most vulnerable link in this extended system is the lineshafting. Pumping from great depths is impossible, due to the lineshaft's being too small in diameter to transmit properly the added torque requirement, or due to limiting conditions on the driver resulting from the shaft weight or from physical distortion of the lineshaft and its resulting effect on the pump element.

The submersible motor removes this depth obstacle to pumping equipment and makes new sources of water available for our future progress and expansion. The submersible motor converts electrical power to mechanical power under water, and the primary problem is to protect the electrical components while simultaneously providing

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suitable motor bearings. Due to the importance of the seal, let me briefly discuss the major requirements for a satisfactory operation.

A satisfactory seal to separate two fluids is rather easily obtained when the two parts have no relative motion. The parts may be fabricated together, or compression-type seals such as O-rings can be used successfully for extremely high differential pressures. The sealing of two fluids through parts having relative motion, such as a mechanical rotary-type seal, requires lubrication and cooling of the contact surfaces, if dependable and extended seal life is to be expected. This, in general, requires the passage or circulation of one of the two fluids between the contact surfaces. Present-day mechanical seals are capable of achieving the necessary lubrication and cooling with a very small quantity of fluid passage. It should also be recognized that the nature of some submersible motor constructions, by necessity, limits fluid passage to one direction.

There are three successful submersible-motor approaches on the United States market at the present time. The basic motor-sealing arrangement often alters the application methods and must be described in order better to appreciate the proper application and limitations of each type of submersible unit. By classification, these motor constructions are (1) the oil-filled motor, (2) the wet-stator motor and (3) the dry-stator motor.

(1) *The Oil-Filled Motor.* In the manufacture of the oil-filled motor, use is made of conventional varnish or enamel types of insulated wire and conventional slot insulation. The basic stator insulation is then achieved by filling the motor with oil, which acts as an insulation, cooling medium and motor-bearing lubricant. The sealing problem of keeping oil in the motor and water out, in general, is accomplished by a mechanical seal, meeting the general requirements previously discussed. It is immediately recognized that proper sealing of the motor is dependent upon an oil reservoir, in conjunction with a positive means of insuring flow of oil through the seal. This is accomplished by providing an internal fluid pressure greater than the well pressure. The resultant motor life is dependent upon the differential pressure and its effect on seal leakage in conjunction with the size of the oil reservoir. These requisites are accomplished in various ways.

One notable variation of the oil-filled motor incorporates a mercury seal in conjunction with a balance chamber, which minimizes the differential pressure between the motor-insulating oil and the well water. This arrangement also meets the seal requirements previously outlined, but it is limited with regard to operating speed and detrimental effects from well contamination. The leads of the oil-filled motor may extend from the stator through a static-type seal, or the necessary cable connection can be made at the motor by use of the internal motor oil as a potting compound.

(2) *The Wet-Stator Motor.* The wet-stator motor is wound with a water-resistant insulated wire and thus obtains its primary sealing or protective action in a most effective manner. It is readily seen that the motor windings are basically as dependable as the power cable or leads are for any submersible motor. The leads are continuous with the winding and are extended through the stator by means of a compression-type seal. The motor is initially filled with clean water, to provide bearing lubrication and to act as a cooling medium for the removal of heat from the windings. This cooling action can be made positive by means of an internal pump and circulation system, which is a very desirable feature not readily possible with the other submersible-motor approaches.

In general, a mechanical seal, similar to that incorporated for oil-filled motors, and a pressure-balance diaphragm are used. The purpose of this additional sealing arrangement is further to protect the motor from abrasives or well-water contamination. A variation to the seal is a filter arrangement which, of course, has reduced the effectiveness against contamination and abrasives.

(3) *The Dry-Stator Motor.* The dry-stator motor is in effect a combination of the two previous designs. The stator is wound with methods and materials similar to those used for the oil-filled motor. The stator is statically sealed by an extremely thin liner, by fabrication methods or compression-type seals at the stator ends. The leads may extend through another static compression-type seal or may incorporate a compression-type disconnect arrangement at the motor.

It should be recognized that the leads seal is vital in this type of construction. The sealed stator is usually filled with a plas-

tic, fluid or other compound, to aid the dissipation of heat from the windings. The motors may be oil- or water-lubricated and will usually incorporate a filter or a seal of the Klozure or mechanical type, in conjunction with a pressure-balance arrangement as discussed for the Wet-Stator Motor, again to protect against well contaminants. When oil is used, this seal will probably be of the more elaborate mechanical type.

All three types of submersible motors will generally incorporate sleeve-type radial bearings and tilting pad-type thrust bearings, and are at present limited to squirrel-cage induction-type motors. They all will be very similar with respect to electrical performance and will usually include a service factor. It will be seen that each particular type of motor construction and features must be closely coordinated with the pumping-element requirements and limitations, in order to achieve maximum effectiveness as a submersible unit.

Basically, the pumping element must first meet the head and capacity requirements of a given job. In meeting these hydraulic requirements, the power required by the pump must be less than the rated motor output over the expected operating range. This usually requires a pump having a non-overloading characteristic, and most deep-well turbine pumps have this characteristic. The pump hydraulic thrust must be balanced within the pump or supported by the motor thrust bearing and usually requires coordinated design, to provide the necessary thrust capacity.

Semi-open impeller construction is favored by some manufacturers, as it will in general produce more water for a given size of pump and total pumping head, but its most important advantages are in its ability to handle solids without "sand locking" during successive start-stop operations and in its ability to withstand wear better. This, of course, is a very desirable feature and assures against a possible, damaging locked-rotor condition, which can only be cured by pulling the unit. In withstanding wear, it maintains a constant loading condition on the motor in terms of power and thrust. However, such construction does impose a higher thrust load on the motor and presents a slightly greater adjustment problem.

Mechanically, the bowl assembly must be accurately aligned with the submersible motor, and must provide suitable strength to support

the weight of the motor and the hydraulic thrust of the pump, and to maintain the required alignment through all phases of installation and operation. Simultaneously, the suction intake must provide adequate water-passage area and a means for passing and protecting the leads past the bowl assembly. As a combination, these considerations pose a problem which can be greatly minimized through coordinated design of the motor and pump elements.

In addition to these rather general pump requirements, a properly coordinated pump and motor design will vastly improve the effectiveness of the basic motor or electrical seal under all conditions of operation, and especially under the more severe starting and stopping conditions. To be successful, the submersible pump must be considered as a submersible unit and applied accordingly.

Equally important is the link of electrical power transmission through the power cable to the submersible motor. The power supplier normally provides power to the load center or meter at rated voltage. Between the meter and the motor will occur a voltage drop. However, it is necessary that the submersible unit maintain suitable voltage at the motor for starting and running conditions, and the power-cable size must be conservatively selected in accordance with the particular electrical design. In addition, the insulation must be water resistant and able to resist mechanical damage during installation or operation. Damage to the power cable may result in damage to the motor.

The head assembly must support the weight of the unit, the power cable and the column full of water. The exact discharge-pipe and power-cable connections can be easily engineered and fabricated for the surface requirements in a most appealing manner.

Now that we have a better understanding of what a submersible unit incorporates, let us evaluate the application advantages:

(1) *Deep Settings.* The primary purpose of a submersible unit is to remove the lineshaft limitations and to permit pumping at greater depths. In addition, the replacement of the mechanical power transmission, linked with more efficient electrical power transmission, results in a higher over-all pumping operation, even though normal dimensional limitations on a submersible motor reduce to a small degree the efficiency of the conversion of electrical to mechanical power. These are important advantages to deep-well pumping, and

the submersible pump now shifts the limiting pumping depths for water to the size of wells and well productivity.

(2) *Crooked Wells.* The submersible pumping unit makes it possible to pump from wells which in the past have not been used or, if used, have been pumped at restricted flow rates. Here again, the submersible unit's success is mainly due to the elimination of the power-transmitting lineshaft. The size of a unit that can be placed in a given well depends upon the degree of crookedness. Where wells are reasonably straight, the pumping capacity is limited by the fact that the water must pass over either the bowl or motor element in order to enter the pump. Pumps and motor elements are generally sized on a nominal basis, to permit satisfactory water passage by the respective element and with due consideration to normal yields from a given well size. That is, a nominal 10″ pump or motor element will actually be 9¼″ maximum O.D., which will permit water passage up to 600 to 800 gal per min in a satisfactory manner. Allowance for passage of the power cable may complicate the usage of some units in a particular well, but this is not the usual case.

(3) *Usage of Full Motor Output.* By elimination of the lineshaft, the submersible applies the full motor output to pumping action and thus produces a greater capacity or head for a given motor rating. This difference can be of major magnitude for deep settings, or where units involving smaller power ratings are concerned, as the lineshaft loss in such cases may be a high percentage of the motor output. In other words, we still have a power transmission-line loss, but this loss occurs prior to the motor conversion of power and does not affect the motor output. This loss must be considered when evaluating over-all performance in terms of efficiency, but results in a more useful power for pumping action and in greater hydraulic output for a given motor rating.

(4) *Ease of Installation.* The elimination of the lineshaft has results reaching farther than its direct absence for installation purposes. It eliminates the need for manufacturing and handling exacting lengths of respective column, tube and shaft, required to provide proper lineshaft-bearing spacing, and permits the use of longer, easier-to-handle column sections. In place of the shafting, and perhaps enclosing tubes, is only the need for securing the power cable to the

column for support purposes. In general, the average submersible installation will require about one-third the amount of time required for a lineshaft turbine.

(5) *Surface Appearance and Lack of Noise.* The possibility of concealing the surface equipment in an underground pit or in an extremely orderly manner above ground, plus its noiseless operation, makes the submersible unit very attractive to the municipalities. It permits integration of their water-distribution system into residential areas with very little expense and few complaints of noise. These units may be either shallow setting, direct booster stations or primary water pumps in very deep wells.

(6) *Maintenance Reduction.* The elimination of lineshafting and the accompanying packing-box seal or lubrication reservoirs makes the submersible unit highly desirable for automatic system operation. Further, it reduces the need for maintenance personnel to replenish such oil reservoirs, surface packing or other surface seals periodically. The elimination of the surface seal is very attractive to the industrial user.

The starting and control methods are important to all applications. As may be expected, the starter and control means are basically simple and will vary with the type of motor and complexity of the operation. Some submersible-unit manufacturers furnish component controls, in order to incorporate necessary alarm systems for the motor-oil level or other features important to their motor. Otherwise, starter controls incorporating overload and locked-rotor protection are generally satisfactory. Magnetic starters, as generally applied for squirrel-cage induction motors of a similar rating, which incorporate three-leg overload protection with circuit breakers or heaters of the ambient compensated type, are preferred and strongly recommended. Reliable lightning protection should always be provided and, due to the excellent ground surrounding the submersible motor element, the ground connection, preferably, should be made to the suspension column. Special controls should be added as conditions warrant. Such controls may include low-water-level cutoffs to prevent damage from the pump's breaking suction, time-delay relays to prevent cycling damage to the unit, and pressure or other control switches.

I believe that the submersible unit possesses at least one application feature that will eliminate some of your pumping problems and will undoubtedly reduce your operating costs. The present high quality of submersible units on the market today makes it worthwhile to consider some of the advantages of a submersible application and its potential improvements to your pumping operations. In this respect, I wish to offer the services of Fairbanks, Morse & Co. to help you fully evaluate your prospective submersible applications.

SUPERVISORY CONTROL SYSTEMS

BY R. H. BABCOCK AND R. E. BURRELL*

[*Read September 18, 1956.*]

The field of supervisory control is an extremely wide one, and one which is not unfamiliar to water-works people. In this discussion we shall deal with a particular aspect of supervisory control: namely, remote control and supervision. We shall describe methods and operation of remote control systems and discuss language and terminology which is probably somewhat unfamiliar to many of you. Many of the terms used in the field of remote control come from the communications industry, as remote control involves transmission of data and therefore is a form of communication.

One generally accepted definition of remote supervisory control is "the control or supervision of a process or operation from a distance, using a minimum number of channels". In your industry, this generally means remote operation of pumps or valves with supervision of water levels, pressures, or flows. By "remote" we mean a distance of anywhere from a few miles up to many miles. Telemetering, the remote recording or indicating of a variable, is very much a part of remote supervisory control. Through one form or another of telemetering, most remote supervision is accomplished. For instance, an operator may push a button or throw a switch to control a pump, but in order for him to know the effect of the pump on his system, a telemetered record or indication is required.

Remote supervisory control systems can be separated into terminal equipment and transmission equipment. It is rather difficult to differentiate between the transmitting and receiving ends of a system, as usually the control and supervisory data or signals are transmitted in opposite directions, with the result that each end of the system is both a transmitting and receiving terminal.

As terminal equipment in a typical system, there would be switches to control valve or pump operation; signal lights to indicate that

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a particular function was "called for" and to "report back" that the operation was performed; telemeter transmitters and associated measuring equipment; telemeter receivers to indicate or record important variables; and power supplies, filters, and multiplexing equipment, to separate signals and apply them to the transmission circuit in a logical arrangement.

The simplest type of remote control would be a switch at one end of the system which would put power on or off a transmission circuit to start or stop a pump, or open or close a valve, at the other end of the system. In this operation, a 60-cycle a-c or a d-c signal could be used simply by connecting the power supply through the switch. The choice between a-c and d-c signals would probably depend upon the type of channel used for transmission. If leased wires are used, lower rates apply for d-c transmission circuits. Also, when d-c transmission is used, there is less chance for interference due to pickup, which is usually 60-cycle a-c. In addition, circuit characteristics, such as inductance or capacitance, have much less effect on d-c than on a-c signals. These reasons usually result in the selection of d-c transmission, even though a separate power supply is required.

If two signals are to be transmitted over a single pair of wires, it is feasible and economical to use d-c for one and 60-cycle a-c for the other. Simple filters at each end of the system separate the signals so that they can be transmitted simultaneously. The use of a-c and d-c over a pair of wires is a form of multiplexing, a term encountered more and more frequently in telemetering and remote control. Multiplexing simply means transmitting more than one signal over a single channel. In the past, remote supervisory systems have been relatively simple, and when more than one signal was required, the usual practice was to use a pair of wires for each, or to use polarized d-c or two wires and ground for the most economical operation. Now, however, systems are becoming more complex. It is not unusual for a system to require a dozen or more signals in either direction. Some of these data must be continuous, while other data may be on a selective basis. Obviously, it becomes impractical, and many times impossible, to obtain sufficient wire pairs for each signal, or even for each pair of signals. The answer is to multiplex the signals in one of several ways. There are two general types of multiplexing: time multi-

plexing, in which the signals are transmitted sequentially over a period of time; and frequency multiplexing, in which signals are transmitted as audio-tones simultaneously.

The first method involves bringing all signals through a sequencing switch at the transmitting end, which switches the signals one at a time onto the common transmission channel. A similar switch at the receiving end switches receiving equipment in synchronism with the transmitting units. This system is used in some telemetering applications, where all signals can be brought into a common switch point, and where the time lag is not important. An advantage of this type of multiplexing is that a d-c signal can be used, permitting use of low-cost telephone facilities. This advantage is overweighed by the lack of flexibility often required in an extensive water-distribution system, where it would be impossible to have a common switching location. Also, signals transmitted by automatic systems have to be transmitted in the same direction, and this fact makes the system rather impractical for supervisory control. To transmit in the opposite direction, it is necessary to interrupt the automatic sequence.

The second method, frequency multiplexing, is much more flexible. In this system, audio-tone generators are keyed by telemeter transmitters or by control functions. Each signal is transmitted as a different tone. All tones between approximately 300 and 3,000 cycles per second can be transmitted over a voice channel leased from the phone company, or over a pair of private wires. As the usual spacing of the tones is about 100 to 125 cps, about 20 signals can be transmitted simultaneously. At the receiving end, selective receivers select only a particular frequency and pass that signal to the telemeter receiver or controlling mechanism. The frequency multiplexing system is extremely flexible, as transmitters and receivers can be placed at either end of a system for transmission in either direction. If the system is extensive enough or complicated enough so that channel space is crowded, tones can be combined or coded to increase the number of signals over the same channel. Voice transmission can be used on the same channel by using either the upper or the lower end of the channel for signaling and leaving sufficient band width for voice.

Telephone voice-transmission circuits are designed to transmit audio frequencies. These tone signals will pass through standard cir-

cuits, which include repeaters and switchboard devices. This means that the tones will be transmitted in the same manner as a regular voice signal and will be amplified, to permit transmission over practically unlimited distances.

Some supervisory control systems use coded d-c or a-c pulses as control signals. These systems involve a great number of relays and do not permit telemetering. The type of supervisory control required by the water-works industry will generally involve telemetering plus control. The frequency-multiplexing system will undoubtedly prove to be best for many of these applications.

A typical, remote, supervisory control system can thus be visualized as a group of telemeter transmitters and receivers. Even the most complex system merely means adding more of the same type of equipment. We should, perhaps, discuss this equipment in some detail. One of the simplest types of telemetering is the impulse-duration type. In this variety, impulses are transmitted whose length or duration is proportional to the measurement. Figure 1 illustrates a typical impulse-duration transmitter. The measuring element, in this case a pressure element, positions a cam contactor in relation to a constantly rotating cam. Whenever the contactor is away from the cam, a switch is closed and a signal or pulse is transmitted. As the measurement increases, the pulse length increases. Any standard type of measuring element can be used to position the contactor.

Because the transmitter consists essentially of opening and closing contacts, any type of signal (d-c, a-c, audio tone) can be transmitted. Also, any type of channel can be used for impulse-duration transmission. Changing circuit characteristics have little effect on this system, because the duration of the impulse rather than the magnitude is used.

Figure 2 illustrates a typical impulse-duration recording receiver. In this unit, a cam switch similar to that used in the transmitter generates an impulse, whose duration is proportional to pen position. We then have two signals present in the simple receiver relay circuit. One signal is proportional to the measurement, while the other is proportional to receiver pen position. If there is any difference, or error signal, a motor is energized, which drives the pen to a position corresponding to the measurement, and the error signal is reduced to

zero. The system is fundamentally a very simple servomechanism or feedback mechanism, similar in principle to most precise control systems in use today.

The telemetering equipment is available in a number of modifica-

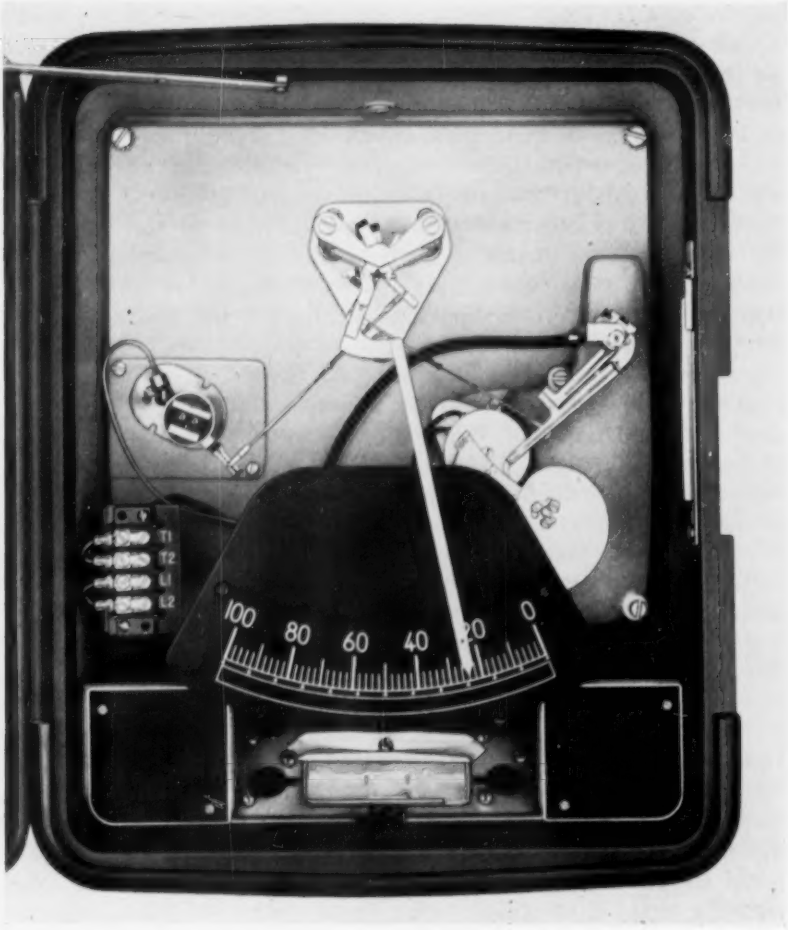


FIG. 1. TELEMETER TRANSMITTER WITH INDICATING SCALE—INTERIOR VIEW (*The Foxboro Co.*).

tions. Single and dual indicating or recording transmitters and receivers are standard equipment. Recently, the receiver has been made available as a 6-record recorder, which will receive inputs from 6 separate transmitters or audio-tone receivers and record each meas-

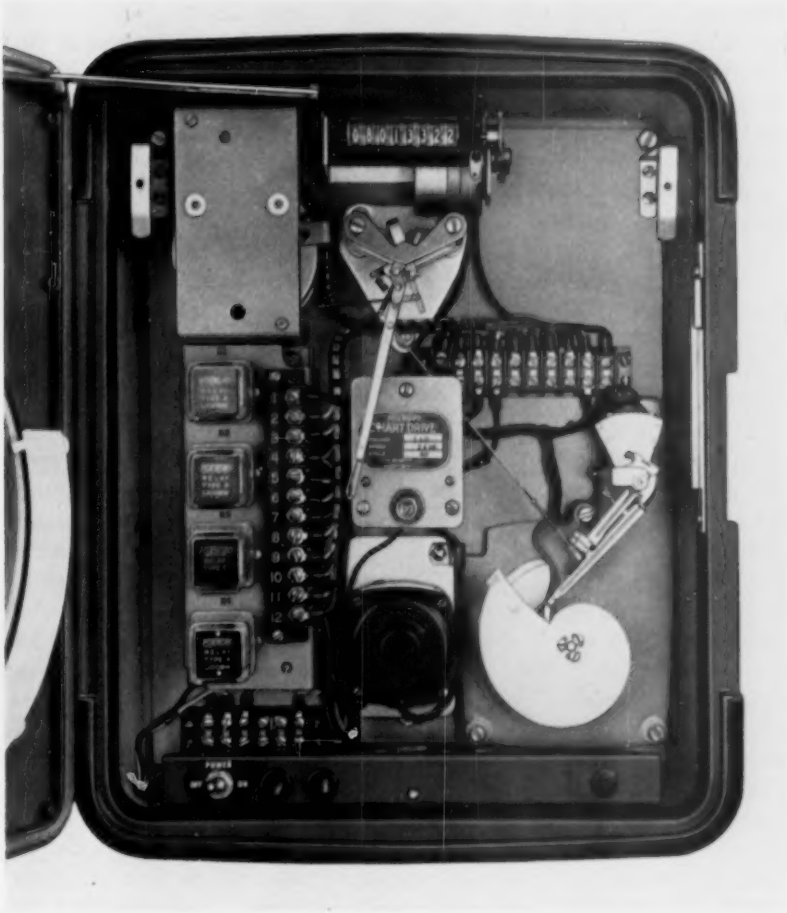


FIG. 2. TELEMETER RECEIVER WITH TOTALIZER—INTERIOR VIEW (*The Foxboro Co.*).

urement in a distinctive color on a single chart. Contacts can be added for automatic alarm or control in transmitter or receiver. Totalizing counters can be incorporated anywhere in the system.

An audio-tone unit, used in frequency multiplexing, is illustrated in Figure 3. The equipment contains a stable frequency generator and amplifier in the transmitter, and an extremely selective tuned circuit, amplifier, and output stage in the receiver. The equipment is furnished by a number of reliable manufacturers of communications equipment, such as Motorola, Westinghouse, Hammarlund, Lenkurt, and a number of others. It is furnished for rack or cabinet mounting. Every effort has been made to provide reliable electronic circuitry in this equipment, and it is used extensively as a transmission technique in such applications as air-to-ground and mobile communication.

Other terminal equipment in a remote-supervision control system will consist of a combination of familiar units: switches, signal lights, relays, and valve or pump operators. Each application requires a different combination of these units for optimum operation and performance.

Most of the transmission in this industry will probably be accomplished over leased or private wires. While microwave and radio are excellent methods of transmission, the economics involved usually do not justify the expense of this equipment. The choice then usually lies in the type of wire line or circuit for any particular application. For one or two signals, a continuous pair of wires or one wire and a ground are usually suitable. For a greater number of signals, additional wire pairs are necessary, or a voice channel may be used. While telephone-company rates vary from one locality to another, average rates are somewhat as follows: For a d-c pair, the cost from one exchange to another is $.75 per mile per month. A pair of wires for a-c transmission will run about $1.50 per mile per month, while a voice channel can be leased for about $3.00 per mile per month. The requirements of each application will determine which circuit should be used. Future expansion should always be considered. If a d-c circuit or circuits are chosen, additional signals will require additional circuits as well as terminal equipment. If a voice channel is used, signals can be added simply by providing additional terminal equipment.

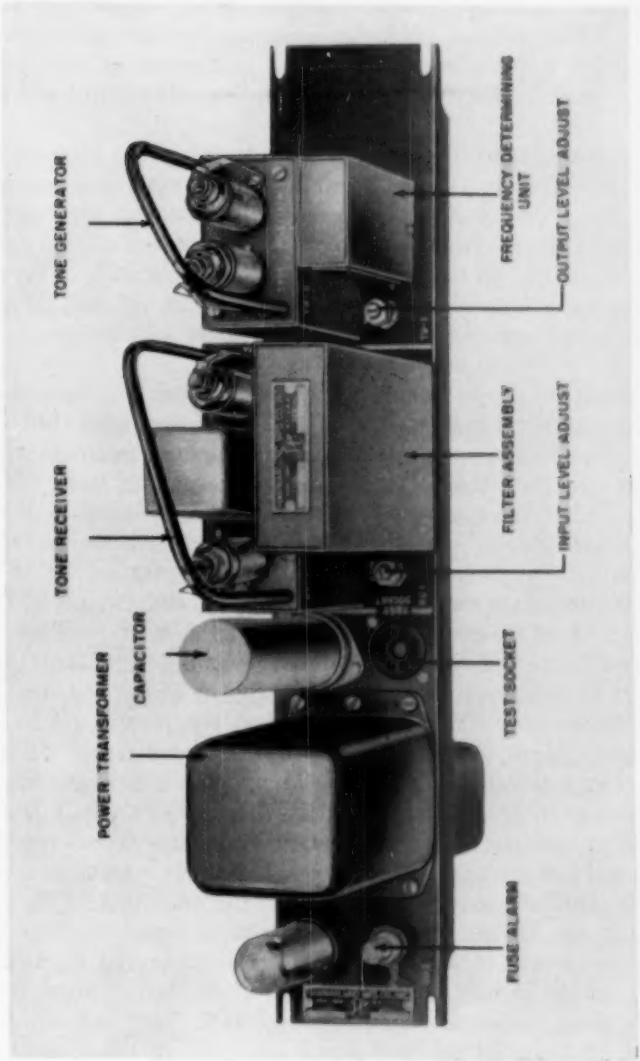


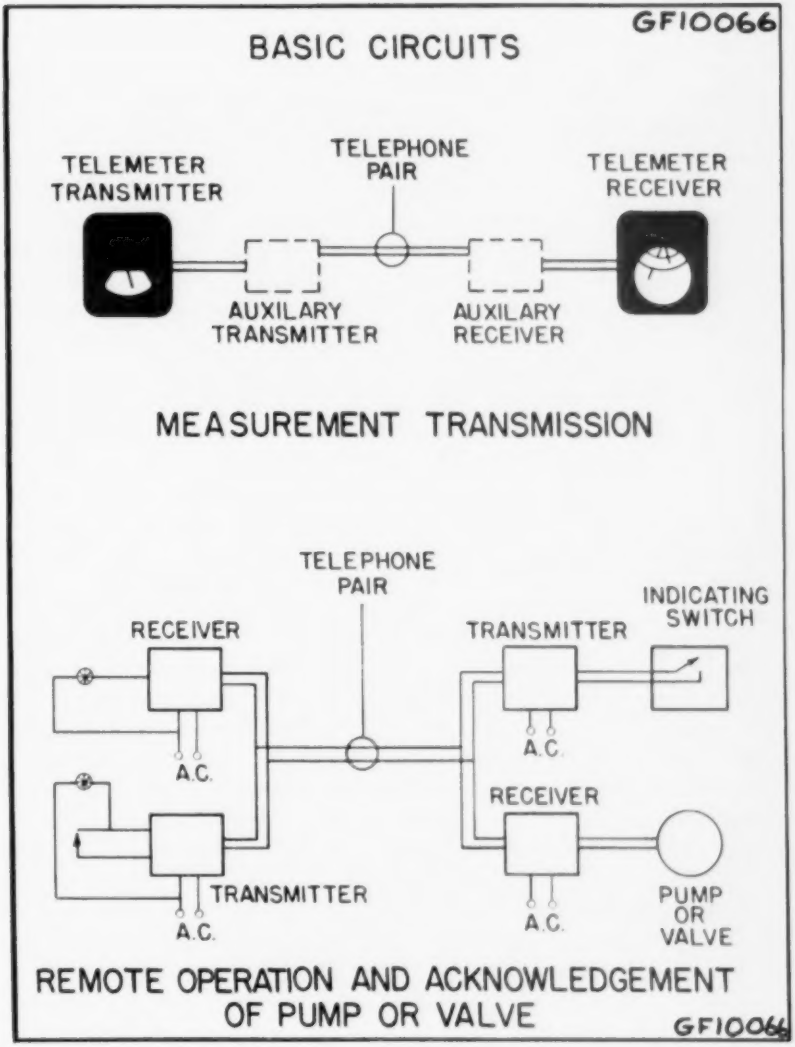
FIG. 3. AUDIO-TONE UNIT USED IN FREQUENCY MULTIPLEXING.

Complete systems are now available for any supervisory control problem. These are not packaged systems, but are tailor-made for the particular application by combining equipment of the type described to provide effective and economical remote control and supervision.

The term "supervisory control system" infers the presence of an operator to carry out certain functions. If we now eliminate in our thinking the necessity that the operator be present at the equipment in order to control it, we have arrived at supervisory control systems as presently used. In the case of supervisory control systems utilizing telemetering for measurement and remote control, we are adding one more factor not included in the usual local installation—namely, distance.

Through the use of supervisory control systems we can now operate pumping stations, valves, etc., at great distances from their actual location. In addition, we are provided with acknowledgment of their operation and the effect of their operation, such as flow, pressure, level, etc. Since there are two basic functions necessary to a supervisory control system—namely, observation of a measurement and response to that measurement in terms of pump operation, valve operation, etc.—there are two basic supervisory control circuits (Fig. 4).

The first of these, measurement transmission, is familiar to all of you and is used in common telemeter installations which many of you have. In order to make this supervisory in nature, it is necessary to add a means of remotely operating valves and pumps and receiving an acknowledgment of their operation. The second circuit illustrates this, showing a switch and pilot light attached to a transmitter. Closing of the switch actuates the pilot light, to indicate that you desire the pump or valve to operate and, at the same time, completes a circuit to a receiver at the pump or valve. The receiver actuates a motor starter or other auxiliary equipment, and the operation of the pump or valve closes an indicating switch. This actuates a transmitter, which sends an acknowledging signal to the receiver and illuminates a pilot light at the control end of the system. Therefore, in actual operation, closing the switch illuminates the pilot light, indicating that the operation is called for, and actual operation of the equipment is indicated by illumination of a second pilot light.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BASIC CIRCUITS
TELEMETER TRANSMITTER
TELEPHONE PAIR
TELEMETER RECEIVER
AUXILARY TRANSMITTER
AUXILARY RECEIVER
MEASUREMENT TRANSMISSION
TELEPHONE PAIR
INDICATING SWITCH
RECEIVER
TRANSMITTER
A.C.
A.C.
RECEIVER
TRANSMITTER
A.C.
A.C.
PUMP OR VALVE
REMOTE OPERATION AND ACKNOWLEDGEMENT OF PUMP OR VALVE
GF10066

FIG. 4.

It is obviously economically impractical to lease telephone pairs for each operation you wish to perform. Therefore, the transmission links are reduced to a minimum through the use of audio-tone transmitters, polarized relays, a-c - d-c signals, and other systems for transmitting simultaneous signals over the same transmission link. We should also mention at this point mechanical multiplexing which, in essence, performs the same function, except that the transmission is not simultaneous.

Through combinations of these two basic circuits, all supervisory control systems are built. They can be likened to building blocks. If we can keep this in mind, a good deal of the mystery behind this type of operation is removed.

As an illustration of a typical supervisory control system in a small city, let us take the case of a supervisory control system for the city of Hoisington, Kan. (Fig. 5). There are three wells discharging to a line which is the intake to a booster station. The booster station, in turn, discharges to the water treatment plant which, in turn, pumps the water via a high-lift pumping station to the system and an elevated tank. It is desired to control each of the wells and the booster station remotely from the water treatment plant and, at the same time, to operate the high-lift pump in response to the reservoir level. In this case, a basic control circuit of the type illustrated in Figure 4 is provided for each of the wells and the booster station, there being a transmitter and receiver at each well and at the booster station, and a similar transmitter and receiver for each well and the booster station at the main control panel. A switch and two pilots (namely, the called-for light and the acknowledgment light) are supplied for the wells and the booster station. It is, therefore, possible to start or stop the pumps on any part of the wells or the booster station from the water treatment plant. In addition, interlocks are provided, so that the booster station cannot run unless at least one of the wells is operating, and the well pumps cannot operate unless the booster station is operating. The reservoir level is automatically controlled by the reservoir-level recorder. Through selector switches the high-lift pumps then can also be operated manually. In addition, a clear-well level recorder-indicator-controller prevents the high-lift pumps from being operated in the event the clear-well level is low.

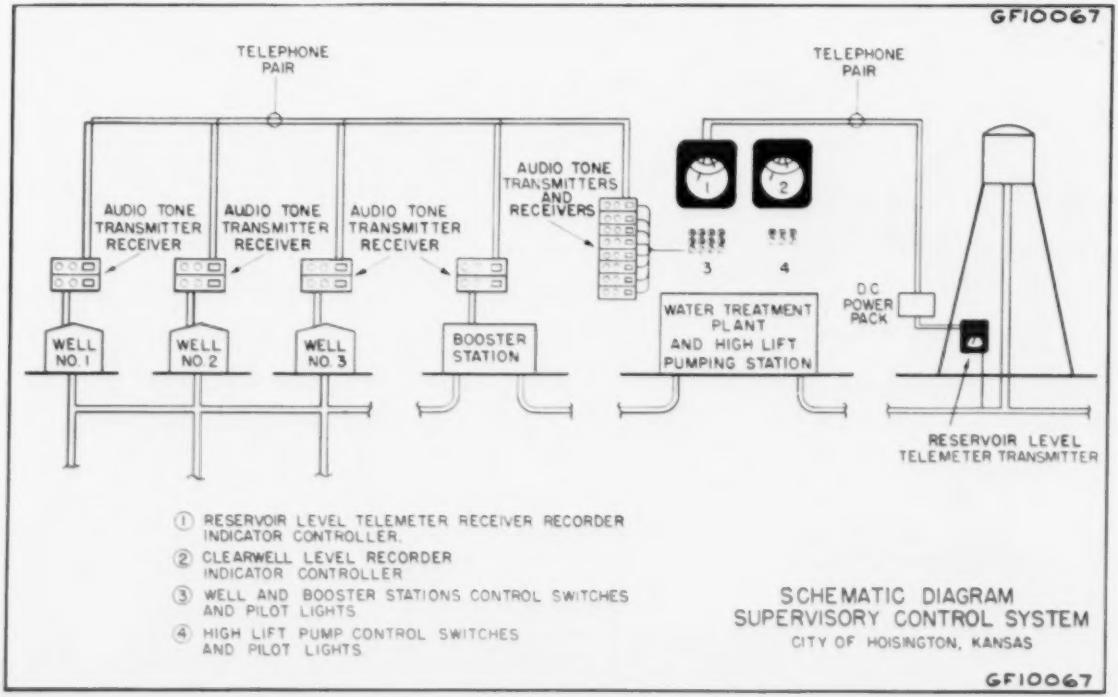
GF10067
TELEPHONE PAIR
TELEPHONE PAIR
AUDIO TONE TRANSMITTER RECEIVER
AUDIO TONE TRANSMITTER RECEIVER
AUDIO TONE TRANSMITTER RECEIVER
AUDIO TONE TRANSMITTERS AND RECEIVERS
1
2
3
4
D.C. POWER PACK
WELL NO. 1
WELL NO. 2
WELL NO. 3
BOOSTER STATION
WATER TREATMENT PLANT AND HIGH LIFT PUMPING STATION
RESERVOIR LEVEL TELEMETER TRANSMITTER
① RESERVOIR LEVEL TELEMETER RECEIVER RECORDER INDICATOR CONTROLLER.
② CLEARWELL LEVEL RECORDER INDICATOR CONTROLLER
③ WELL AND BOOSTER STATIONS CONTROL SWITCHES AND PILOT LIGHTS
④ HIGH LIFT PUMP CONTROL SWITCHES AND PILOT LIGHTS
SCHEMATIC DIAGRAM
SUPERVISORY CONTROL SYSTEM
CITY OF HOISINGTON, KANSAS
GF10067

FIG. 5.

Analyzing this system part by part, you will see that control of the wells and the booster station requires four remote-operation circuits. Measurement of reservoir level is a single-measurement transmission circuit; clear-well level cut-offs and high-lift pumping station control are local circuits. You will observe that there is only one telephone pair running from the water treatment plant to the booster station and wells. This single channel carries eight circuits. This system differs from running the power supply directly to each of these locations from the water treatment plant only in that all signals are being carried over the same transmission link simultaneously. The reservoir level, coming from a direction different from the wells and booster station, travels over its own transmission link. If the physical arrangement had been different, all of these signals could have traveled over the same transmission link (Figures 6, 7 and 8).

The previously described installation concerned the use of audiotone transmission. In an installation requiring a fewer number of signals, it is possible to use polarized relays or a-c - d-c signals. As an example of the latter, we shall use the supervisory measurement system for the Canal Pumping Station at the Salem-Beverly Water Supply Board (Fig. 9). In this case, it is desired to measure the flow through the Canal Pumping Station from the Ipswich River to the Putnamville Reservoir. When under gravity-flow conditions, it is desired to measure the flow from Putnamville Reservoir to Wenham Lake. Therefore, an instrument was provided which could measure the flow in both directions. An auxiliary contact on the pump actuated a four-way solenoid valve, to reverse the pressure leads from the primary device to the telemeter transmitter, thereby permitting the telemeter transmitter always to read upscale. In addition to this, it completed a circuit to the pumping station, which actuated an operation pen on the recorder. The same signal actuated a relay, selecting the proper totalizing counter so as to totalize the flow in opposite directions on separate counters. The measurement transmission was by d-c signal and the operation-indication transmission by a-c signal. Through the use of power packs and filters, the operation-indication part of the system was separated from the measurement part of the system with both traveling over the same transmission link simultaneously.

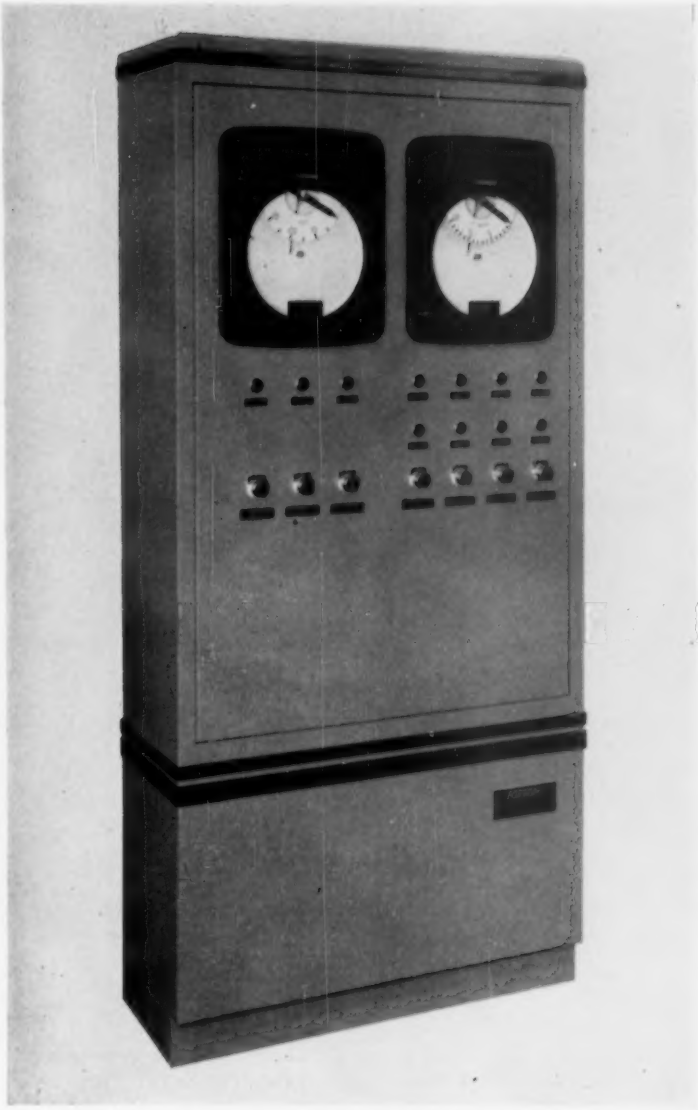

FIG. 6. CONTROL CABINET FOR HIGH SERVICE AND FIELD WELL PUMP FOR CITY OF HOISINGTON, KAN.—FRONT VIEW (*The Foxboro Co.*).

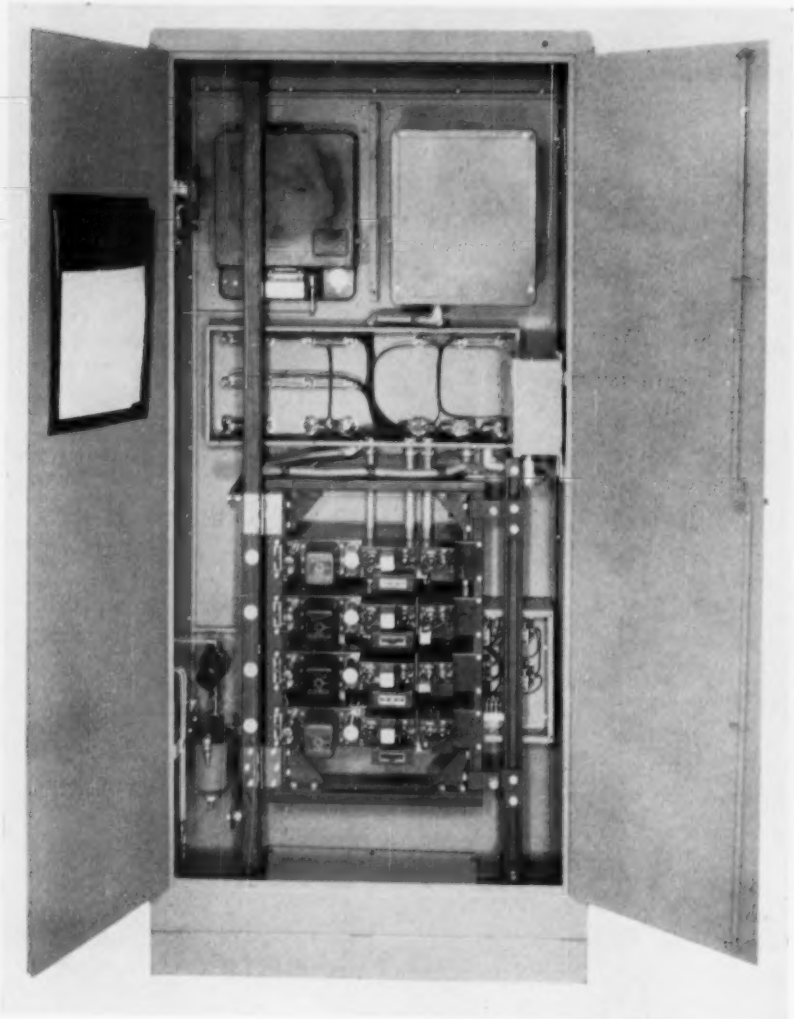

FIG. 7. CONTROL CABINET FOR HIGH SERVICE AND FIELD WELL PUMP FOR CITY OF HOISINGTON, KAN.—REAR INTERIOR VIEW (*The Foxboro Co.*).

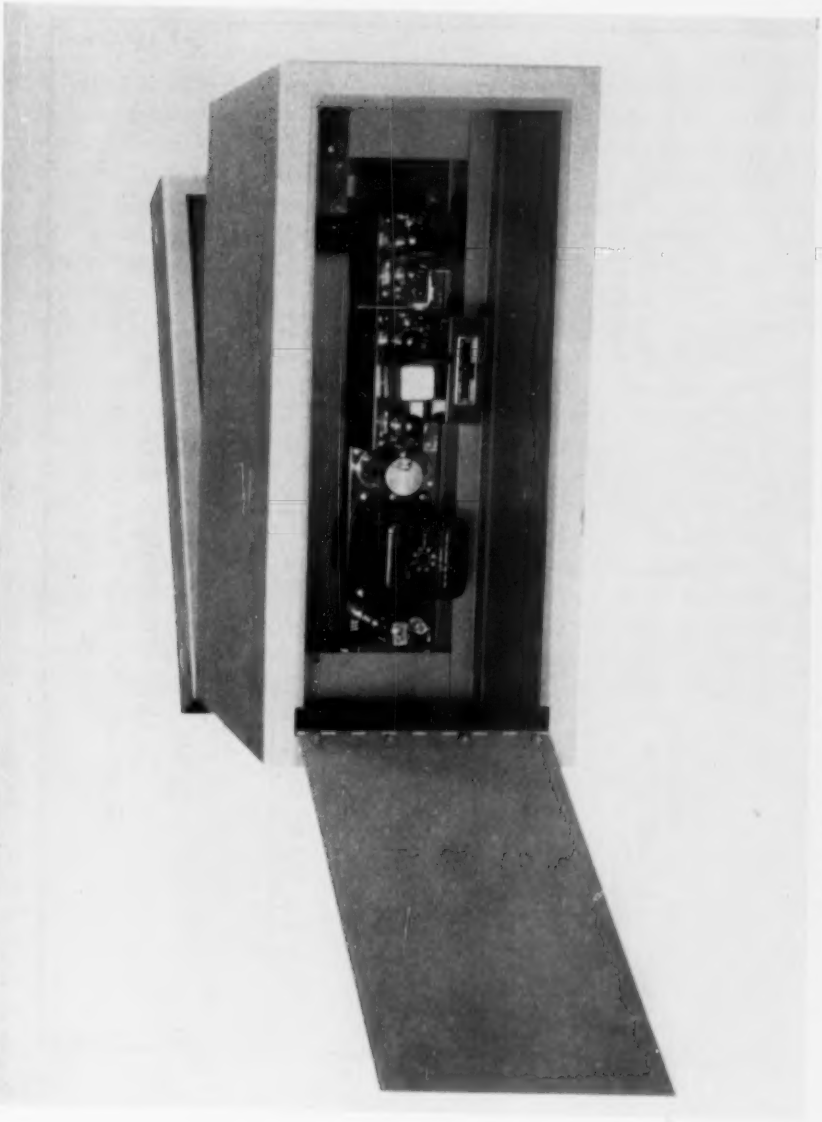

FIG. 8. AUDIO-TONE TRANSMITTER RECEIVER FOR CITY OF HOISINGTON, KAN.

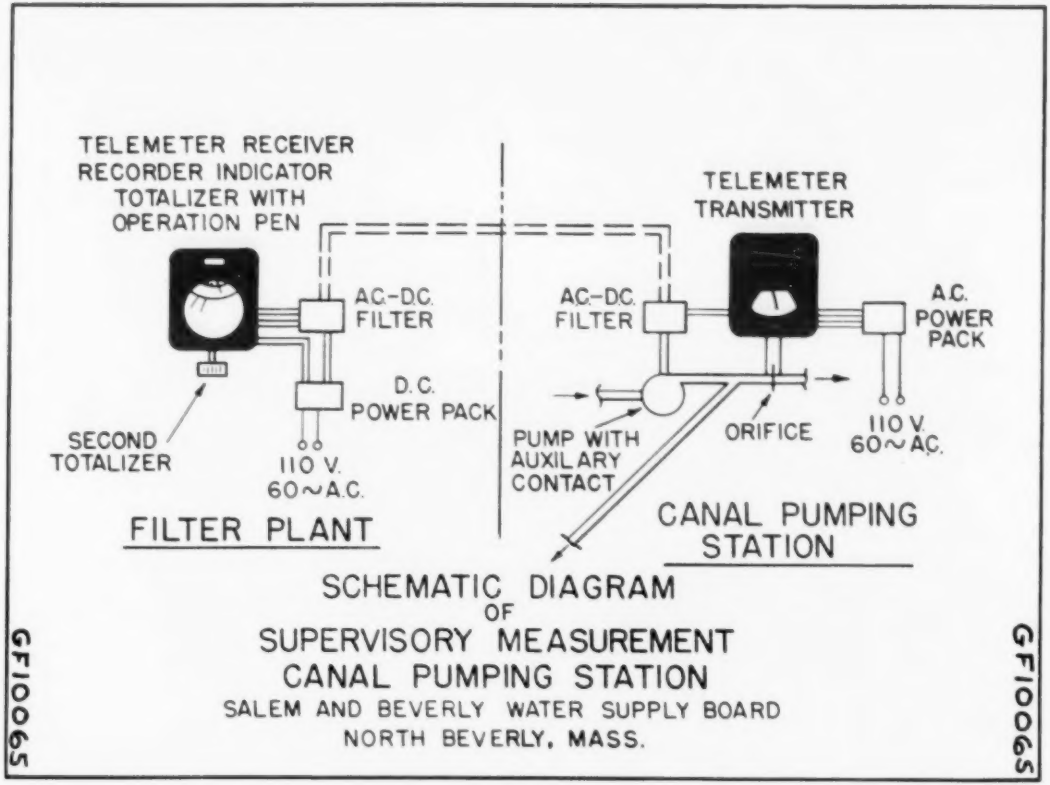
TELEMETER RECEIVER
RECORDER INDICATOR
TOTALIZER WITH
OPERATION PEN
AC-DC
FILTER
D.C.
POWER PACK
SECOND
TOTALIZER
110 V.
60~A.C.
FILTER PLANT
TELEMETER
TRANSMITTER
AC-DC
FILTER
A.C.
POWER
PACK
PUMP WITH
AUXILARY
CONTACT
ORIFICE
110 V.
60~AC.
CANAL PUMPING
STATION
SCHEMATIC DIAGRAM
OF
SUPERVISORY MEASUREMENT
CANAL PUMPING STATION
SALEM AND BEVERLY WATER SUPPLY BOARD
NORTH BEVERLY, MASS.
GF10065
GF10065

FIG. 9.

A more elementary but very useful type of supervisory control involves the use of power packs and filters. Through the application of these devices it is possible to perform such operations as reservoir high-level alarm or pump shutdown on high level, remote operation of single pumps, or remote indication of equipment failure. These systems do not entail remote measurement and, therefore, a principal source of cost is eliminated. The equipment is available from a number of manufacturers and in some areas can be leased from the telephone company. It has the advantages of being inexpensive and reliable. Its application is, however, limited to single elementary operations.

In general, supervisory control systems of the type that have been under discussion lend themselves best to distribution systems. For that reason, they should be of interest to us here in New England. Most of us are concerned with distribution systems, and a relatively small percentage with complex treatment. The advent of such equipment as audio-tone, transmitters and receivers and other systems permitting continuous, simultaneous signals over the same transmission link now makes supervisory control a practical addition to any water treatment and distribution system. Equipment of this type has been in use for many years for supervisory control of pumping stations on oil- and gas-transmission lines. Its benefits are more efficient operation, through continuous supervision of installations by properly trained personnel.

CURRENT SPECIFICATIONS FOR CAST IRON PIPE AND HOW TO ORDER TO SPECIFICATIONS

BY THOMAS F. WOLFE*

[*Read September 19, 1956.*]

It seems particularly appropriate to present a paper on Cast Iron Pipe Specifications before the New England Water Works Association. The first standard specification developed for cast iron pipe was adopted by this association 54 years ago—in 1902. Two years later the American Society for Testing Materials published its Specification for Cast Iron Pipe, and in 1908 the American Water Works Association adopted a standard specification for cast iron pipe and fittings. All of these earlier specifications were somewhat similar as to design formula and covered only pit-cast pipe and fittings.

Following development of the centrifugal casting processes in the early 1920's, a manufacturer's specification was used until a Federal Specification, which included centrifugally cast pipe, as well as pit-cast pipe, was adopted in 1931. This was the first major change in cast iron pipe specifications in more than 20 years.

The formula used in the determination of thickness in the Federal specification differed in form from the formulas previously used, but contained the same general elements. The design in all specifications was based on internal pressure, plus an arbitrary allowance that was added to the thickness to take care of manufacturing requirements, handling, and all indeterminate stresses. Pipe made in accordance with New England Water Works Association, American Water Works Association and Federal Specifications worked satisfactorily, even though the design formulas did not take into account trench loading, surface loads and impact. The arbitrary allowance, plus the factor of safety, seems to have been large enough for the conditions under which the pipe worked.

In the course of time it became evident that while pipe made to the older specifications gave satisfactory service, the design procedure

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was not consistent with modern engineering practice. Increased knowledge of metallurgy and the development of the centrifugal processes of casting had resulted in an increase in tensile strength from 11,000 lb per sq in. in full-length bursting in the case of pit cast pipe, to upwards of 18,000 lb per sq in. bursting tensile strength in centrifugally cast pipe.

In order to take advantage of the increased strength of cast iron as well as to apply engineering methods to the design of pipe, the American Standards Association Committee A21 was organized in 1926. The New England Water Works Association was one of the sponsors of this Committee, along with the American Gas Association, American Society for Testing Materials and the American Water Works Association. The Committee was assigned the task of developing new specifications for cast iron pipe, to include centrifugal casting and the standardizing of various types of joints. This Committee was composed of pipe users, pipe producers, engineers and those having general interest in pipe matters. Thomas H. Wiggin, a member of the New England Water Works Association, has served as Chairman of the Committee ever since its inception.

At all times the Committee was aware of the fact that in the preparation of a specification, they should have in mind the interests of the smaller users of pipe. For this reason, they felt that the specification should be in such form that even the smallest buyers, who might not have inspection staffs, would be assured of getting the same quality of pipe as the larger users, who might either have their own inspection departments or retain outside inspection organizations. The interests of these users was protected by provisions in the specification to the effect that producing companies would be required to furnish sworn statements regarding the tests required in the specifications themselves.

Before developing a new design formula, an extensive series of tests were undertaken by the Committee. Many of these tests were carried on at the University of Illinois, Iowa State College and Ohio State University. In addition to the test work, a vast amount of information and records of experience were gathered and studied.

The new method represents a truly scientific basis of design. It includes not only water pressure and water hammer, but also earth

pressures and truck loads, which vary not only with the depth of cover but with the method of installation. The type of trench bottom used has a definite effect on external forces resulting from backfill and traffic loads. Tests were made that simulated various methods of laying pipe, and the bearing values so determined were related to three edge test results made in the laboratory. This relationship changes with various sizes of pipe and represents an important factor in determining wall thicknesses.

Six types of trench bottoms were considered and evaluated, four of which are in common use for underground pipe installation (see Fig. 1). Flat-bottom trenches, with or without tamped backfill, are the most common methods of laying water pipe. Pipe supported on blocks is the poorest method of laying underground pipe, particularly if the backfill is not tamped. Shaping the bottom of the trench to fit

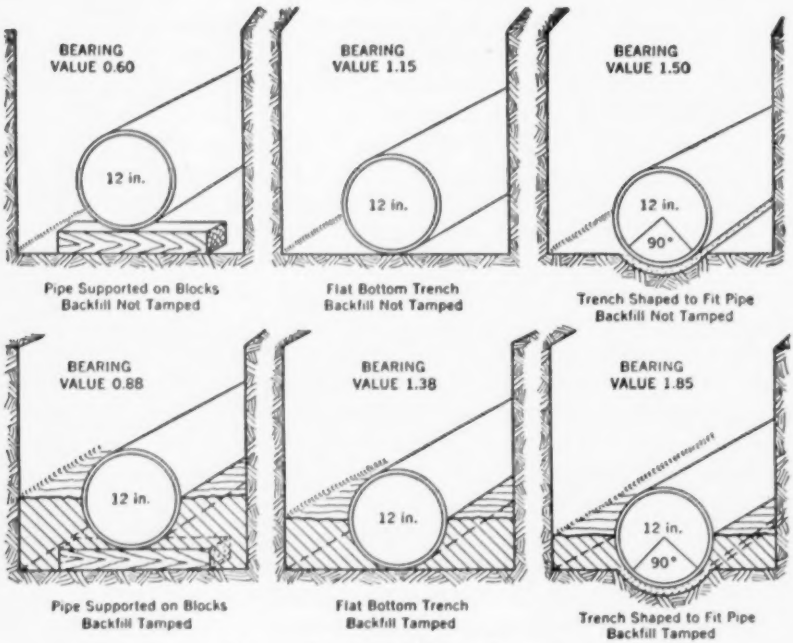

FIG. 1. TYPES OF TRENCH BOTTOMS.

the pipe gives the greatest support to the pipe and is generally practiced in sewer construction, and might be advantageous for water pipe in special cases. Tamping backfill up to the center line of the pipe is very desirable in all cases.

The additional factors of design dealing with trench loads resulted in new class designations that were not related to pressure alone. For the most commonly used sizes, there is the same number of classes under the new specifications as previously existed under the older specifications.

It was desirable that outside diameters that enter into jointing operations should conform to those in common use, and they were taken directly from the former AWWA Specifications. Whatever the outside diameter of a pipe now in service may be, if it is an AWWA standard, there is a similar outside diameter in the ASA specification.

The ASA specifications covering cast iron pipe and fittings for water are as follows:

A21.2	Pit Cast Pipe
A21.6	Centrifugally Cast in Metal Molds
A21.8	Centrifugally Cast in Sand Lined Molds
A21.10	Short Body Fittings—3 Inch to 12 Inch
A21.11	Mechanical Joint

There are four tables in each pipe specification. The first table gives dimensions of pipe, and bell-and-spigot joints. The second gives class thicknesses, diameters and weights without reference to pressures, depth of cover or trench conditions. The third table gives thicknesses for the standard trench condition; that is, a flat bottom trench with tamped backfill and with 5 ft of cover. Table four gives pipe thicknesses for laying conditions other than standard and for depths of cover of 3½ and 8 ft, as well as the standard 5 ft of cover.

This might sound confusing, but with a copy of the specifications before you, use of the ASA specifications is just as simple as was the case with the older ones.

Suppose we follow the procedure required to use the specifications. The first thing to determine is the working pressures. Next we

should determine the type of trench bottom to be used for installation. Laying condition B (a flat bottom trench with tamped backfill) and 5 ft cover, represents the condition which is most commonly used and embraces a vast majority of pipe-laying jobs. Let us assume we desire to purchase 8-inch centrifugal pipe, for 150 psi pressure, for this laying condition. We would refer to table 6.3 or 8.3 in the specification. You will note that the portion of the table shown uses the two numbers:—6.3 *and* 8.3. Table 6.3 appears in Specification A21.6, which relates to metal mold centrifugal pipe. Table 8.3 appears in Specification A21.8, which covers sand-lined mold centrifugal pipe. These tables are identical in respect to thicknesses, and either one may be used. The differences in the tables relate to variations in weight which are due to different laying lengths.

Reference to this table would show a required thickness of 0.41 in. for the conditions which have been determined.

PORTION OF TABLE 6.3—8.3
STANDARD THICKNESSES OF
PIPE CENTRIFUGALLY CAST
Class 150—150-psi Pressure

Size (in.)	Thickness (in.)	Outside diam. (in.)
3	0.32	3.96
4	0.35	4.80
6	0.38	6.90
8	0.41	9.05
10	0.44	11.10
12	0.48	13.20
14	0.51	15.65
16	0.54	17.80
18	0.58	19.92
20	0.62	22.06
24	0.73	26.32

Having determined the thickness of pipe required as 0.41 in., we refer to Table 6.2 or 8.2 and find that 8-inch pipe of this thickness is designated as class 22 pipe. This is the minimum thickness made in accordance with the specification.

TABLE 6.2—8.2
STANDARD THICKNESSES OF
PIPE CENTRIFUGALLY CAST

Nom. diam. (in.)	Thickness class	Thickness (in.)	Outside diam. (in.)	Inside diam. (in.)
6	22	0.38	6.90	6.14
	23	0.41	6.90	6.08
	24	0.44	6.90	6.02
	25	0.48	6.90	5.94
8	22	0.41	9.05	8.23
	23	0.44	9.05	8.17
	24	0.48	9.05	8.09
	25	0.52	9.05	8.01
	26	0.56	9.05	7.93

If we should desire 8-in. pipe for 250 psi pressure, laying condition A with 8 ft of cover, we would again refer to the tables, in this case Table 6.4 or 8.4, and find a thickness requirement for these conditions of 0.44 in., which is designated as class 23 pipe.

The same tables also give actual diameters, weights and dimensions of pipe and bell-and-spigot joints.

It will be evident from the table that this same thickness will meet the requirements of 8-inch pipe, up to and including 300 psi working pressure, for any method of laying except condition C (pipe laid on blocks, untamped backfill). In respect to 6-inch pipe, the minimum thickness meets the requirements for all pressures through 350 psi, with 8 ft of cover, for any method of laying except condition C (pipe supported on blocks, backfill not tamped). If your standard procedures provide for laying pipe in this way, you will require a greater thickness than for other laying conditions.

It is to be borne in mind that use of the thicknesses shown in the specifications meets the minimum requirements of the various factors of the design. At times, it is possible that several different laying conditions may take place on a single pipe-laying project. Even though a particular method of laying may be specified on contract work, continuous engineering inspection may not be provided, and

laying conditions might change. Department forces may lay pipe without being aware of the method of laying intended when determining the design thickness. Additional depth of cover may be required, due to changes of grade made to meet field conditions. As a result of this, some engineers feel it is desirable to design on the basis of a thickness which will be sufficient to meet the requirements of any reasonable method of laying which may occur on the job.

TABLE 6.4—8.4
STANDARD THICKNESSES OF
PIPE CENTRIFUGALLY CAST

Size (in.)	Working pressure (psi)	*8 ft of Cover* Laying condition A	B	C	D
		Thickness—*in.*			
6	50	0.38	0.38	0.48	0.38
	100	0.38	0.38	0.48	0.38
	150	0.38	0.38	0.48	0.38
	200	0.38	0.38	0.52	0.38
	250	0.38	0.38	0.52	0.38
	300	0.38	0.38	0.52	0.38
	350	0.38	0.38	0.52	0.38
8	50	0.41	0.41	0.52	0.41
	100	0.41	0.41	0.56	0.41
	150	0.41	0.41	0.56	0.41
	200	0.41	0.41	0.56	0.44
	250	0.44	0.41	0.56	0.44
	300	0.44	0.44	0.60	0.44
	350	0.48	0.44	0.60	0.48

We find that some buyers prefer, for any one of a variety of reasons, to continue to use pipe of approximately the same thickness as they have previously used. This is very easy to accomplish. For example, if a user of Federal Specification pipe wanted to order pipe under the ASA specifications that would have a thickness approximately the same as his present pipe, he could easily do so.

In the case of class 150 Federal Specification pipe, he would simply order class 22 in the 6″ and 8″ sizes, and class 23 in sizes from

10″ to 16″. In the case of class 250 Federal Specification pipe, he would order class 24 pipe for the 6″ size, class 25 for 8″, 10″ and 12″, and class 26 for 14″ and 16″. The thickness of class 150 and class 250 Federal Specification pipe and the ASA classes suggested are as shown here:

ASA Class Designation
to Compare with WW-P-421

Size	Thickness WW-P-421 class 150	ASA thickness	ASA class designation
6″	.37	.38	22
8″	.42	.41	22
10″	.47	.48	23
12″	.50	.52	23
14″	.55	.55	23
16″	.60	.58	23

Size	Thickness WW-P-421 class 250	ASA thickness	ASA class designation
6″	.43	.44	24
8″	.50	.52	25
10″	.57	.56	25
12″	.62	.60	25
14″	.69	.69	26
16″	.75	.73	26

There is a growing tendency on the part of many pipe buyers to use pipe with thickness slightly greater than that determined by specific design factors. This serves to provide an additional factor of safety and is desirable where first cost is not the most important item to be considered. The costs of trenching, laying, making joints and backfilling remain the same, regardless of pipe thickness, so that only a small increase in overall cost will result, due to the slight additional cost of the pipe itself.

American Standards Association Specification A21.11 covers a mechanical joint for use on cast iron pressure pipe and fittings made in accord with the ASA pipe specifications. The specifications cover

a joint only. Pipe thicknesses and classes are determined separately from the various pipe specifications. This joint has been steadily gaining popularity for the past 25 years and is now the most commonly used joint on new construction. The joint as specified may be used with pipe, fittings, valves or hydrants.

Since there is only one mechanical-joint outside diameter for each nominal diameter pipe, this should be borne in mind when connections are made to old pipe. When the spigot to which a connection must be made is too large for the socket of a mechanical joint, an adapter may be used. This adapter has a fitting bell and a mechanical joint socket. If such a fitting is not available, a standard sleeve may be used to transpose from the existing larger spigot to the spigot end of the mechanical joint pipe.

American Standards Association specifications A21.10 cover short-body fittings, 3-in. through 12 in. These fittings are rated at 250 psi water pressure plus water hammer. They may be furnished with mechanical joints when so specified. The principal difference from the older fittings is in laying lengths. AWWA fittings in sizes 4-in. through 60 in. are covered by AWWA C100-54T.

One other ASA Specification dealing with water pipe is that pertaining to the cement lining of pipe. Cement lining has been used for well over 80 years and has been successful in preventing tuberculation, and insures high flow capacity regardless of age of pipe. A number of flow tests have been made on cement-lined pipe that has been in service as much as 30 years, and flow coefficients in the Williams-Hazen formula of as much as 140 have been found. A large percentage of all cast iron pipe now furnished for water service is cement lined.

All of this may sound complicated, but essentially the ordering of pipe under new specifications is as simple as was the case with older specifications. The buyer of pipe, as in the past, must know the pressure to be carried, and under the new specifications, having decided on a trench condition and a depth of cover, he is able to select the class thickness that his needs indicate and from then on specify ASA class .... cast iron pipe.

USE OF McILROY FLUID NETWORK ANALYZER IN PHILADELPHIA

BY V. A. APPLEYARD*

[*Read September 19, 1956.*]

The city of Philadelphia is the third largest city in the United States—having a population of over 2.1 million people. The Water Works has a very interesting history of its growth, but it will suffice here to say that we have cast-iron pipe in our system which is over 125 years old. We have approximately 2,900 miles of pipeline, and the sizes vary from 93 in. to 4 in. Tied up to this distribution system we have approximately 520,000 customers. We do not go beyond the city limits, but the city comprises 130 square miles of area (Fig. 1). We have ten different service areas, which in most cases are clearly defined by having the distribution valves shut down along a specific service border. However, in other areas, 2 or more pumping systems blend in the distribution system without any valves specifically being down. In other words, in some cases we operate as though we had independent pumping and distribution systems—and in other cases. we operate a large area of the city and serve it with a number of pumping stations. We have 5 filter plants and 18 pumping stations—some of which pump raw water, and others clear water—as well as clear-water booster stations. Last year, the average day's consumption was 370 mil. gal. of water, half of this water being supplied from the Delaware River and the other half from the Schuylkill River.

One would think that a city as large as Philadelphia would be fully developed by this time, but such is not the case. Last year there were 11 farms over 100 acres in size within the city limits, most of this undeveloped area being in the Northeast section of the city. However, during the past 5 years, the Northeast section has been filling up with residential, industrial and commercial building, such that in the not too distant future a saturation point will be reached. Also, in the Southwest section of Philadelphia a large redevelopment project is being designed, about which more detail will be found below.

*Chief of Water Operations, Water Department, 1103 City Hall Annex, Philadelphia, Pa.

Our department has a specific multi-million-dollar improvement program for the next 5 years. We are rebuilding all filter plants; we are renewing or replacing some pumping stations, and as far as distribution system is concerned, we have a very active program of building additional storage facilities; building additional trunk-main capacity in existing built-up areas, and building new trunk-main capacity, as well as extending grid system into newly developed areas. We also have a re-lay and cleaning and lining program to rehabilitate the older parts of the distribution system. With this extremely active program, the McIlroy Network Analyzer was an absolute "must", if we were to get accurate engineering designs which were economical in original capital outlay—as well as economical in operations—and at the same time conform to our basic service criteria.

During the summer of 1954, Prof. M. B. McPherson of Lehigh University was working for our department on hydraulic design. He spent the best part of 2 months making a complex analysis of the operation of our Belmont High Service system. The gathering of data was relatively simple and not very time-consuming. However, the analysis of flows vs. head losses through the system under all the varying predicted conditions of load definitely indicated that a tank should be installed on this system. Further analysis was necessary, in order to establish the best possible location of this tank from the standpoint of operations of the system, and at the same time within the practical limitations of where there was land available to erect such a tank.

At the end of the summer, Professor McPherson and I went to Cornell University and repeated his complete analysis on the first model of the Network Analyzer under the direct supervision of Dr. McIlroy. In one day we reviewed his analysis and added a number of other operating conditions onto the system, to get a much more complete study of this system. I recite this story to demonstrate how quickly an analysis can be made with the Analyzer, as compared to using the Hardy Cross method as applied by an engineer. Immediately after this tryout, an Analyzer was put on order, which provided for 312 pipelines, 11 sources of water into the pipeline network, and 73 loads, which are take-offs of water from this same network. It was received and erected in a large room in the City Hall Annex in January, 1956 (Fig. 2). The installation required about 2 weeks.

PHILADELPHIA, PA.
MAP OF TRUNK MAINS
WATER DISTRIBUTION SYSTEM

FIG. 1.

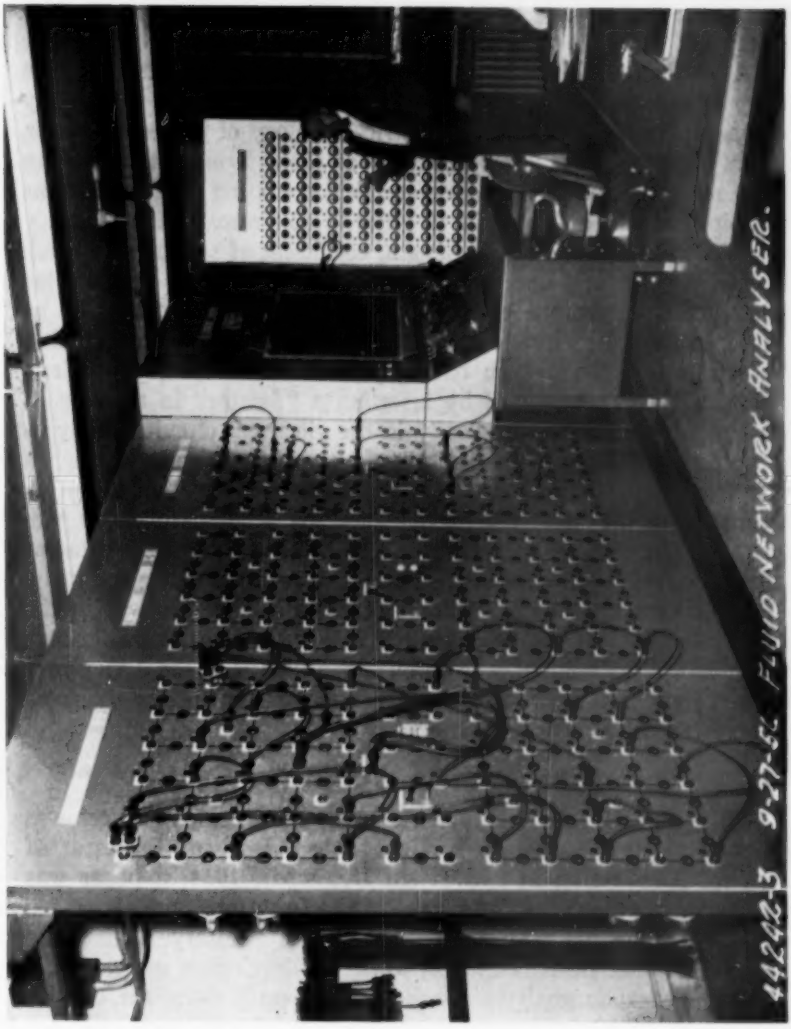

FIG. 2. FLUID NETWORK ANALYZER IN PHILADELPHIA.

This installation is quite simple because the complicated wiring is all done in the factory and carefully checked for operation before shipment.

A number of articles have been written about the details of the theory of operation of this Analyzer. Therefore, I shall merely say that the unit produces an exact electrical analogy of your distribution system. The Analyzer is *only as good as the information which you use to set up the problem.* Accurate field operating data, as well as good pipe records, are essential in order to obtain maximum accuracy of analysis. For instance, size, length, coefficient of roughness of each pipeline, plus at least one set of operating conditions of the pipeline system under study are essential. The distribution network to be studied is duplicated by electrically tying together the same number of electrical circuits as you have pipelines in your study problem. Each pipeline is reproduced by inserting a "fluistor" in the circuit. This fluid resistor acts electrically in the electrical circuit exactly as each pipeline functions hydraulically in the distribution system. In other words, the flow of water through the pipeline behaves in accordance with the basic Hazen-Williams law of fluid flow. As you know, the loss of head varies at the 1.85 power vs. flow. This factor made it extremely difficult to duplicate this performance electrically. Actually, the secret of the performance of the Analyzer was in the final development of the "fluistor." As direct current flows through the "fluistor," the voltage drop through the tube is at the 1.85 power of the current flowing through it and, therefore, it exactly simulates the performance of a water pipeline.

Brief History of Analyzer

The original idea of an electric pipeline network Analyzer was conceived about 1930 by H. L. Hazen, then Assistant Professor of Electrical Engineering at M.I.T. In December, 1934, a paper was published in the New England Water Works Journal* by H. L. Hazen and T. R. Camp, then Associate Professor of Sanitary Engineering at M.I.T., which described their work on developing an electrical means of hydraulic analysis. Back in those early days, the electric resistor was used to represent a pipeline, and it obviously was not

*This Journal, 48:383, Dec., 1934.

very accurate, because it acted as a direct function with the exponent of 1.

In 1943, Camp published another article on this same subject,* pointing out that in 1936 the Hardy Cross method of analysis was developed, as well as graphical methods of analysis developed by E. Aldrich. In 1942, vacuum tubes were used, and in 1943, some time was spent in trying to develop a tube that would act electrically exactly as a pipeline does hydraulically. Several other men participated in a minor way in the development of this Analyzer.

World War II interrupted this basic research, but at the end of the war, Dr. M. McIlroy, then on the staff of M.I.T., decided to concentrate on this problem. He solved the vacuum-tube design problem and then went on to design the complete Analyzer.

Dr. McIlroy received his Doctor's degree from M.I.T., on his thesis of the research and development of this Analyzer. He went to Cornell University about 1948 and, under a research grant, he completed his first model. He worked very diligently on this project and strained his heart badly, and met an untimely death in the spring of 1956, when only 53 years old.

Actual Use of Analyzer in Philadelphia

The actual use of the Analyzer in a specific case in Philadelphia occurred in a new residential, commercial and light industrial area in the southwest part of the city, known as "Eastwick" (Fig. 3). This redevelopment will clear some slum areas, as well as build up some low-lying swampy areas, and will ultimately accommodate a suburban section which will house over 50,000 people and will have about 1,100 acres of light industry. It is predicted that this newly developed area will use an average of 8.8 mgd of water. A trunk-main layout and a distribution grid were designed and submitted to our department for study and approval (Fig. 4). We simulated the trunk-main system by plugging into the Analyzer all the pipelines which they proposed in the sizes they recommended. We imposed water loads on the system in accordance with our knowledge of basic use by domestic, commercial and industrial users within the city. We then analyzed the head losses along the pipeline network and found them to be too low in

*This Journal, 57:334, Dec., 1943.

accordance with good economic design criteria. We reduced some of the pipeline sizes to what our engineers felt would be adequate, and again we analyzed the system (Fig. 5). We found that our design had a much better balanced system under normal loads and that it would very adequately handle the maximum hour-maximum day rates, and also the worst conditions of fire flow superimposed on maximum day rates.

During the analysis we imposed fire flows at many locations, 5 of which were very critical. For instance, at one location 26,000-GPM fire demand was imposed in an industrial area; in another critical study, a fire flow of 3,000 GPM was imposed at the highest elevation of ground in the development, which fell in a residential area. We based our study on the use as predicted in the year 1980 and used "C" values as predicted they would be at that time. The final design of this distribution system actually reduced the amount of 30-in. pipe to 24-in. pipe by 11,600 ft, and the 20-in. pipe to 16-in. pipe by 17,000 ft. The saving in the initial cost of installing these pipelines is in excess of $350,000. The complete analysis of this system was done in approximately 2 weeks' time, and it is so complete and so exact that no one can contest the adequacy of this design as against that originally submitted.

So much for the Analyzer in a specific design problem. The apparatus can also be used for operating problems, such as the proposed cleaning and lining of trunk mains in our Roxborough High Service District. We, in Operations, must know in advance how to operate the system with the maximum length of trunk main out of service. This means that the trunk mains and some of the distribution grid must be put on the Analyzer. Then the maximum rates of the seasonal load are imposed on the network as set up on the Analyzer. If the service standards of pressure are not met, then temporary facilities are needed, and the Analyzer can indicate the actual requirements during this temporary period. This can be done in several ways, such as:—bleeding into this area from a higher pressure district; the installation of a temporary pipeline; the installation of several "round connections" from another trunk main, etc. The Analyzer will obviously be of great value in this type of problem, because we are able actually to simulate conditions of the field before,

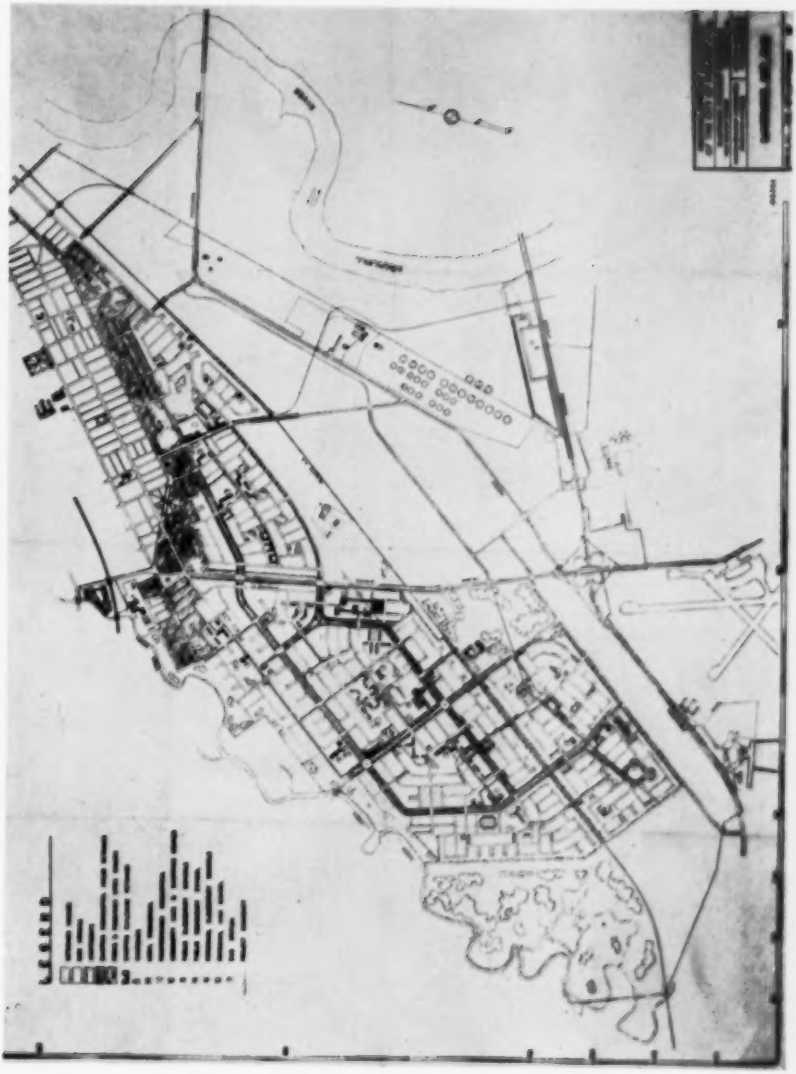

FIG. 3. PLAN OF EASTWICK REDEVELOPMENT.

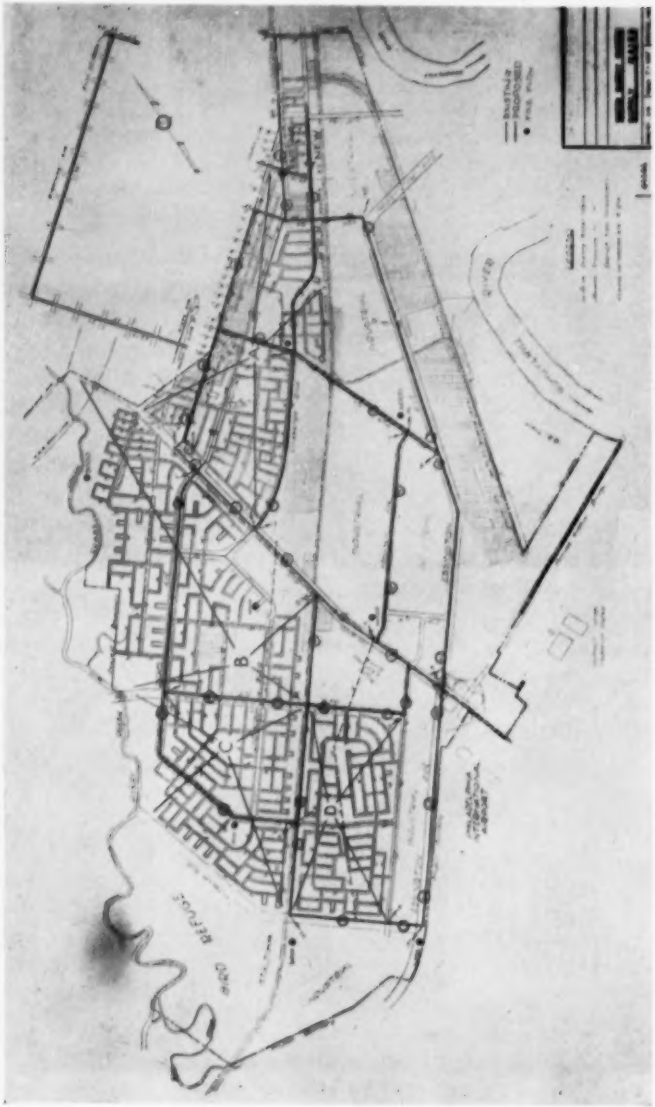

FIG. 4. PLANNED EASTWICK LAYOUT.

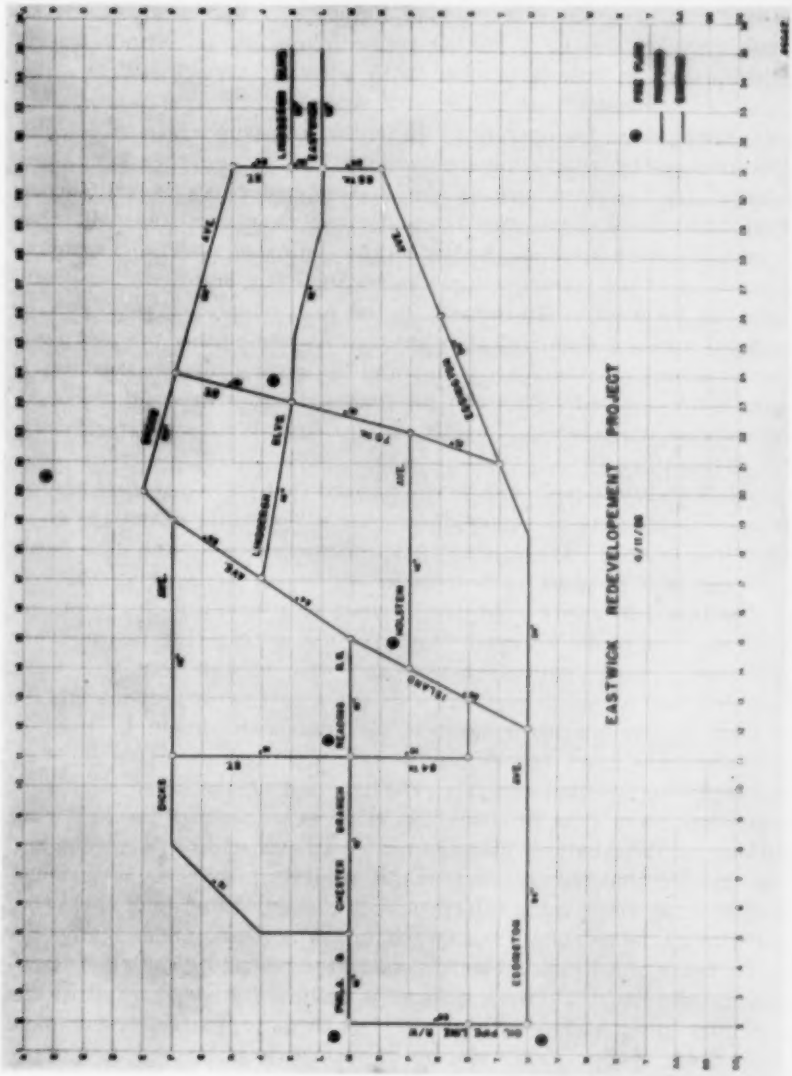

FIG. 5. FINAL TRUNK-MAIN DESIGN.

during and after the cleaning and lining job. This analysis can be done quickly, and each section to be taken out of service can be scheduled in an orderly manner, with adequate service still provided to our customers.

Another use for operations' benefit is to set up a part of the distribution system that is obviously weak in capacity, then simulate a normal day's performance of this system and check it with actual field data. Once the system is exactly the same as in the field, then predicted future loads can be put on the simulated system. The maximum hour of the maximum day can be predicted, and hydraulic gradients can be readily determined. Better yet, temporary steps can be plugged into the electrical circuits, such as adding a temporary pipeline or a temporary booster pump, and the results can be immediately seen and evaluated. This can be done well in advance of the summer season and thereby furnish an opportunity to prepare properly for seasonal loads.

In conclusion it should be emphasized that the Network Analyzer is only as accurate as the engineer that is operating it and the basic data that he uses. There is no "black magic". The object is to duplicate the part of your system under study on the electric Analyzer within practical limits. We do not consider it necessary to pitometer each pipeline to get an exact "C". We use average use figures when developing "load" figures. However, I wish to state that it is quite amazing how close an engineer can come to exactly duplicating the system by using average figures. His judgment should be used to insist on more exact data where the specific information could be very influential in the final analysis. We have not, in the seven months of operation, spent time to check out in an exact manner the field conditions vs. the Analyzer calculations. We have made spot checks and are satisfied that the accuracy of the Analyzer is as close as our engineer can calculate, using tables, etc. It is our definite opinion that we get a much more complete analysis of the network under study, because fewer short cuts are taken than are normally used when hand-calculated. Every alternate scheme is readily studied, as well as the variables in each plan—all of which gives us an extremely complete engineering study. This Analyzer has saved us a tremendous number of hours as well as dollars, and I, therefore, state that we, in Philadelphia, are very much satisfied with this unit.

MEMOIR OF CARLETON E. DAVIS

Carleton E. Davis, Past President of the New England Water Works Association, died January 29, 1957, in Merion, Pa. Born in Brookline, Mass., November 14, 1869, Mr. Davis was graduated from Massachusetts Institute of Technology in 1893. From 1900 to 1904 he was resident engineer for the Newark, N. J., water supply. During the next two years, as engineer for the Isthmian Canal Commission, he was engaged in the construction of water works and sewers in the Panama Canal Zone. In 1905 he became department engineer in the Reservoir Department of the Board of Water Supply of the city of New York, leaving in 1912 to take the office of Chief of the Philadelphia Bureau of Water. He remained in this position until 1923, when he went to Indianapolis as Manager of the Indianapolis Water Co. Two years later, however, he returned to Philadelphia as Manager of the Philadelphia Suburban Water Co. He later became Vice-President and Director and, at the time of his death, he was serving the company as a consultant.

Mr. Davis had been a member of the New England Water Works Association since 1902 and was President in 1918. He was an honorary member of the American Water Works Association and served as president of that association in 1920. He was also a member of the American Society of Civil Engineers and the Engineers Club of New York.

GEORGE C. HOUSER

REPORT OF COMMITTEE ON RAINFALL AND YIELD OF DRAINAGE AREAS

RAINFALL IN NEW ENGLAND*

PART VI. RAINFALL IN CONNECTICUT (*Continued*)

MOUNT CARMEL, CONN.—Elevation 200 feet
Record: January, 1937, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1937	6.35	3.71	3.98	5.64	3.57	3.38	3.02	8.71	3.02	6.38	7.81	2.62	58.19
1938	4.49	2.66	2.25	3.14	4.67	7.81	6.60	2.73	14.81	2.20	3.24	3.53	58.13
1939	3.83	4.76	6.55	4.59	1.18	4.33	1.07	4.69	2.59	5.08	1.50	4.13	44.30
1940	2.80	2.54	6.36	6.35	9.64	4.33	3.59	2.47	3.12	2.04	5.82	2.94	52.00
1941	2.93	2.72	1.56	1.39	3.26	4.04	3.93	5.46	0.03	2.57	4.66	4.62	37.08
1942	4.84	2.77	8.66	0.91	4.60	2.90	5.42	6.31	2.49	3.83	4.89	5.99	53.01
1943	2.73	1.96	5.29	3.91	4.18	4.39	2.69	1.64	1.82	5.58	4.81	1.43	40.43
1944	2.41	1.90	7.59	4.54	1.71	1.91	0.93	1.55	9.52	2.21	8.22	3.49	45.98
1945	2.52	3.86	2.40	4.33	6.85	2.53	3.97	3.70	2.88	2.23	5.13	5.97	46.37
1946	2.15	2.51	1.58	1.86	6.18	2.99	3.14	7.95	3.94	0.86	1.68	2.75	37.59
1947	2.36	2.18	3.27	4.47	4.14	3.83	4.38	3.62	2.41	1.96	8.00	2.80	43.42
1948	3.83	1.55	4.78	5.68	7.19	4.49	2.85	3.25	0.51	2.46	7.12	7.28	50.99
1949	6.93	2.26	2.56	4.16	6.87	0.30	3.33	3.65	4.37	1.88	2.05	2.86	41.22
1950	3.05	3.58	3.45	2.46	4.22	3.79	4.70	4.73	1.01	2.10	5.25	4.23	42.57
Av. 14 Yrs.	3.66	2.78	4.31	3.81	4.83	3.64	3.54	4.32	3.75	2.95	5.01	3.90	46.50

NAUGATUCK, CONN. (Naugatuck Water Co.)
Record: January, 1896, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1896	1.81	7.89	4.87	0.75	2.33	4.91	4.10	3.71	5.42	3.29	3.44	1.49	44.01
1897	4.38	3.21	2.97	2.49	5.71	5.17	16.56	4.52	2.59	1.12	5.91	6.16	60.79
1898	3.98	4.23	2.48	3.78	6.28	0.54	3.00	8.38	2.38	5.04	7.55	3.01	50.75
1899	3.59	3.07	5.11	1.50	2.71	2.55	6.51	0.57	4.54	2.06	2.15	2.74	37.10
1900	3.14	7.03	4.02	1.87	3.66	2.71	2.80	2.10	3.12	3.58	3.80	2.44	40.27
1901	1.67	0.35	7.63	11.44	7.89	0.59	2.94	5.47	4.82	4.24	2.70	9.64	59.38
1902	2.42	5.57	7.76	4.13	2.30	5.48	4.57	3.90	7.05	6.02	0.94	7.42	57.56
1903	2.75	4.47	5.69	2.97	0.46	11.72	3.47	4.92	3.49	2.87	2.20	3.44	48.45
1904	3.84	4.12	4.07	5.11	2.43	3.02	2.11	6.34	6.75	2.33	1.76	2.64	44.52
1905	2.38	1.16	1.92	3.36	1.70	4.30	1.77	3.24	3.13	2.09	1.60	3.39	30.04
1906	2.20	3.88	4.01	3.87	4.22	5.87	5.52	3.59	1.97	6.79	2.14	3.27	47.33
1907	5.93	3.23	1.62	2.76	4.41	3.93	1.83	1.10	10.05	5.35	6.20	4.90	51.31
1908	3.77	4.92	2.15	1.37	5.78	0.70	4.61	4.75	1.73	2.41	1.21	4.21	37.61
1909	3.65	6.19	4.24	8.54	2.40	2.85	1.93	3.55	3.91	1.11	1.88	4.72	44.97
1910	6.63	3.20	1.05	3.64	2.57	2.66	2.63	2.56	1.49	0.30	4.77	1.22	32.72
1911	2.56	2.41	3.52	3.60	1.46	3.79	5.47	6.56	2.12	8.81	4.86	3.11	48.27
1912	1.95	3.06	9.53	4.62	5.44	0.50	4.33	5.17	2.89	3.95	5.66	5.60	52.70
1913	3.52	3.12	7.63	6.17	4.03	1.70	2.53	5.43	3.55	10.64	3.53	3.60	55.45
1914	4.48	4.26	5.74	4.21	2.86	3.69	6.76	3.75	0.43	2.86	3.82	4.88	47.74
1915	10.12	6.89	0.27	1.89	2.70	2.67	4.60	10.30	2.17	3.16	2.59	7.06	54.42
1916	1.54	5.78	3.86	2.86	4.41	5.71	4.36	2.80	3.73	1.39	3.47	2.76	42.67
1917	3.47	2.33	5.29	2.99	3.96	3.89	2.62	5.25	1.71	9.10	0.98	3.75	45.34
1918	4.37	3.64	2.08	4.32	3.74	4.51	3.51	2.92	5.84	1.03	3.25	3.95	43.16
1919	3.24	3.31	7.42	2.92	6.27	2.08	4.43	5.08	7.47	3.67	4.94	2.70	53.53
1920	3.02	4.88	5.11	5.73	3.87	5.74	5.80	1.62	9.28	1.39	4.62	7.99	59.05

* Continued from this JOURNAL 71:1, 82, March, 1957.

NAUGATUCK, CONN. (Continued)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1921	2.92	4.32	2.85	5.03	4.20	4.41	6.96	2.10	3.37	2.38	5.44	2.83	46.81
1922	2.26	2.27	5.34	3.00	6.47	5.06	4.45	4.37	0.83	2.75	1.49	5.22	43.51
1923	8.47	1.29	3.50	4.36	3.44	4.26	1.60	1.97	2.37	6.91	4.71	5.48	48.36
1924	5.59	2.68	1.30	6.91	5.62	1.38	1.76	5.60	5.45	0.26	3.29	2.58	42.42
1925	3.70	3.02	4.19	2.06	4.07	3.35	6.49	2.68	3.49	4.68	3.22	3.44	44.39
1926	2.16	5.97	2.57	2.97	2.09	1.64	4.49	5.19	3.11	3.61	6.67	4.02	44.49
1927	3.26	3.77	1.97	1.95	5.21	2.41	5.56	6.20	1.74	5.65	8.05	5.33	51.10
1928	3.04	4.46	2.95	4.06	1.87	5.66	7.86	5.15	3.37	0.92	2.48	1.05	42.81
1929	5.60	4.25	4.10	6.20	4.69	1.03	0.83	6.25	1.71	5.29	2.35	4.31	46.61
1930	2.62	2.47	4.30	2.15	3.15	4.68	2.51	2.74	2.52	1.72	5.55	2.87	37.28
1931	2.90	2.14	4.61	2.74	3.93	3.65	1.76	3.08	1.19	1.82	1.06	2.80	31.68
1932	4.51	2.26	3.41	2.27	1.55	3.11	3.42	3.88	2.92	4.88	7.65	1.99	41.85
1933	1.85	3.57	5.72	5.01	2.30	2.57	1.57	7.77	5.45	1.98	1.17	3.88	42.84
1934	3.71	4.34	5.26	4.61	5.97	3.48	3.84	3.36	12.16	2.15	3.21	4.12	56.21
1935	4.19	2.96	1.91	1.92	2.35	5.50	3.33	0.84	4.51	0.40	3.59	0.77	32.27
1936	6.83	2.61	8.00	3.79	4.09	4.14	2.12	2.88	3.78	4.27	1.42	7.42	51.35
1937	6.19	3.18	3.37	4.59	4.30	3.64	2.83	6.95	3.05	3.97	5.16	2.06	49.29
1938	5.69	2.83	1.87	3.16	3.50	5.89	10.20	3.47	11.63	1.67	3.86	4.79	58.56
1939	3.60	4.10	5.92	4.41	0.78	3.26	2.86	5.29	3.23	3.34	2.92	3.11	42.82
1940	3.65	2.82	5.47	5.78	4.36	4.54	3.12	2.68	3.07	2.08	5.18	3.06	45.81
1941	2.55	4.30	1.78	1.28	1.99	3.90	9.38	4.53	0.73	2.90	3.42	4.60	41.36
1942	3.59	3.85	7.53	0.81	3.37	3.08	3.51	5.01	3.22	3.06	5.49	6.19	48.71
1943	3.57	2.35	4.15	3.00	6.43	3.90	2.63	3.11	1.53	5.66	5.21	1.06	42.60
1944	2.45	2.34	5.67	4.53	2.03	2.40	3.45	0.99	7.86	1.42	6.35	4.73	44.22
1945	3.58	3.53	2.13	5.34	6.91	3.73	6.65	3.41	3.51	2.00	5.59	5.18	51.56
1946	2.51	2.79	1.70	1.84	7.18	3.08	5.18	8.15	3.93	1.80	1.91	2.75	42.82
1947	2.40	2.84	3.58	4.08	4.79	5.48	5.26	3.10	2.91	1.14	7.41	3.56	46.55
1948	4.50	1.75	4.60	4.69	6.10	4.51	2.54	2.25	0.43	1.80	6.60	6.86	46.03
1949	7.39	3.24	3.34	4.34	5.21	0.88	4.00	2.32	3.98	1.93	1.58	3.04	41.25
1950	3.60	3.96	3.45	3.48	3.91	4.16	5.76	4.25	1.02	1.77	5.58	5.26	46.20
Av. 55 Yrs.	3.80	3.61	4.12	3.77	3.92	3.64	4.27	4.13	3.81	3.25	3.87	4.01	46.20

NEW HARTFORD, CONN. (Richard's Corner Dam)—Elevation 399 feet
Record: April, 1912, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	2.78	3.51	6.81	0.74	4.76	4.96	6.22	2.82	3.82	4.13	6.68	5.81	53.04
1943	2.84	1.94	3.57	3.40	4.83	3.03	2.46	1.54	1.39	5.14	4.54	0.72	35.40
1944	1.79	2.02	4.59	4.33	1.68	4.03	2.46	2.66	6.64	2.15	6.30	4.05	42.70
1945	2.91	4.06	2.07	6.36	7.54	5.78	6.22	6.36	2.70	2.45	5.41	4.32	56.18
1946	2.99	2.25	1.69	2.22	5.77	2.53	6.76	3.36	3.72	1.57	0.94	2.45	36.25
1947	2.89	2.30	3.19	3.96	4.90	3.46	6.07	1.59	2.91	2.46	7.22	2.55	43.50
1948	3.46	2.05	3.75	3.10	5.82	6.86	2.96	1.39	0.26	2.13	5.36	7.14	44.18
1949	6.66	2.62	3.30	3.58	5.53	0.70	2.02	2.72	2.55	2.17	1.97	3.57	37.39
1950	4.29	4.23	3.01	2.82	3.52	5.11	2.50	4.24	1.87	1.91	6.75	6.41	46.66
Av. 38 Yrs.	3.33	2.78	3.44	3.72	3.97	4.03	3.94	4.01	3.82	3.22	4.05	3.36	43.67

NEW HAVEN, CONN.
Record: 1804 to 1829; 1864 to 1868; 1873 to 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.42	2.58	8.01	1.32	3.67	3.06	7.45	10.14	2.15	3.89	4.53	6.49	57.71
1943	3.57	2.42	5.26	3.17	4.05	3.79	2.75	1.22	1.22	4.03	3.30	1.84	36.62
1944	3.60	2.43	7.16	5.01	0.93	1.19	0.73	1.30	9.99	1.99	8.14	3.61	46.08
1945	2.23	3.87	2.98	3.47	5.41	2.11	3.72	6.16	3.00	2.49	5.28	6.51	47.23
1946	2.44	2.51	1.67	1.85	7.47	3.19	2.18	7.83	2.97	0.63	1.67	3.17	37.58
1947	2.75	2.45	2.61	5.21	3.21	4.28	3.67	4.12	3.10	2.30	7.77	3.33	44.80
1948	4.99	2.08	4.48	5.45	7.77	3.60	2.35	2.20	0.70	1.54	4.96	7.88	48.00
1949	5.87	1.95	3.19	6.14	0.12	2.83	2.88	2.95	2.30	2.20	3.59	2.15	37.17
1950	3.31	3.60	2.93	2.40	3.65	3.61	3.83	5.64	1.09	1.70	3.10	4.60	39.46
Av. 100 Yrs.	3.83	3.78	4.68	3.65	3.81	3.39	4.12	4.37	3.59	3.53	3.68	3.78	45.61

NEWINGTON, CONN.
Record: January, 1940, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	2.91	1.84	5.10	5.53	6.58	3.34	2.83	1.74	1.96	2.69	5.51	2.69	42.72
1941	2.11	2.67	1.84	1.06	3.77	3.46	6.33	3.65	0.61	2.22	3.52	3.89	35.13
1942	4.42	2.38	6.06	0.60	3.92	3.47	4.05	4.70	3.27	2.97	6.21	6.26	48.31
1943	2.51	2.06	4.10	3.10	5.89	4.38	2.66	0.83	1.25	5.21	3.90	0.94	36.83
1944	1.86	1.73	4.51	4.53	2.58	3.83	2.60	1.76	9.20	2.65	6.62	3.11	44.98
1945	3.24	3.11	2.27	4.15	5.98	3.63	2.64	3.38	1.86	1.72	4.85	5.68	42.51
1946	2.18	2.28	1.79	2.39	6.31	2.97	4.69	8.16	2.26	0.90	1.25	3.02	38.20
1947	2.50	1.53	2.36	4.72	2.96	4.60	5.08	2.02	3.04	1.93	6.03	1.89	38.66
1948	2.87	1.75	3.50	4.02	4.91	6.02	2.84	2.86	0.59	1.45	5.76	5.40	41.97
1949	5.21	2.62	1.26	4.41	5.88	0.62	2.61	4.52	2.91	2.20	2.25	3.02	37.51
1950	3.72	3.52	2.59	2.92	3.19	3.00	3.22	3.88	1.21	1.48	4.96	4.08	37.77
Av. 11 Yrs.	3.05	2.32	3.22	3.40	4.73	3.57	3.59	3.41	2.56	2.31	4.62	3.63	40.41

NEW LONDON, CONN.—Elevation 47 feet
Record: January, 1871, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	2.86	3.74	6.40	8.44	—	—	—	—	—	—	—	—	—
1941	—	—	—	—	—	—	—	—	—	—	—	—	—
1942	2.93	3.44	6.67	0.64	1.83	2.16	4.80	6.36	1.44	3.59	5.34	6.90	46.10
1943	3.33	2.13	2.96	3.38	4.20	2.61	4.21	2.20	0.45	3.73	2.85	1.78	33.83
1944	2.45	2.41	5.43	4.13	1.04	2.16	0.86	2.18	9.03	1.90	9.40	2.65	43.64
1945	2.55	3.47	2.22	3.38	3.89	2.78	1.72	3.85	1.15	2.82	5.52	5.79	39.14
1946	4.17	2.63	1.88	1.76	4.22	3.54	2.33	8.45	2.37	0.58	1.27	2.26	35.46
1947	3.03	1.34	1.98	5.55	3.98	2.62	3.18	3.07	2.28	2.57	7.76	2.55	39.91
1948	5.41	2.60	4.51	3.59	9.03	2.94	1.65	0.75	0.44	3.55	4.94	2.34	41.75
1949	5.61	3.84	2.41	3.67	2.86	0.01	3.80	3.30	5.71	2.37	3.50	3.85	40.33
1950	3.23	3.04	2.91	2.43	6.77	3.65	2.56	5.03	0.99	1.61	—	3.48	—
Av. 77 Yrs.	4.05	3.61	4.13	3.68	3.42	3.15	3.58	4.28	3.43	3.57	3.81	3.72	44.43

NORFOLK (Litchfield Co.), CONN.—Elevation 1,400 feet
Record: July, 1915, to December, 1935; January, 1939, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1939	2.82	4.56	4.08	5.90	1.83	4.14	1.29	5.54	2.03	4.73	2.32	2.85	42.09
1940	3.83	4.52	6.34	5.83	7.75	4.45	2.48	4.08	3.33	2.43	6.38	2.86	54.28
1941	3.35	2.79	3.13	1.15	4.43	6.81	6.52	3.12	—	2.79	2.96	4.19	—
1942	3.42	1.99	6.76	1.03	4.94	4.09	4.66	1.89	3.75	3.47	7.11	5.16	48.27
1943	3.29	1.96	2.95	3.68	6.33	2.80	3.29	1.02	1.90	4.72	6.56	0.87	39.37
1944	1.84	2.76	4.99	3.97	2.87	6.41	2.20	2.95	5.68	1.78	5.48	3.53	44.43
1945	5.46	4.44	2.41	6.46	8.14	8.58	9.33	4.13	6.70	2.92	5.77	4.87	69.21
1946	2.98	4.05	1.82	2.88	5.40	3.01	5.51	2.82	3.93	2.82	1.51	2.95	39.68
1947	3.61	4.29	4.97	4.16	5.79	4.08	4.60	3.50	3.71	1.86	6.12	3.79	50.48
1948	3.82	2.44	4.40	3.47	5.20	6.83	3.14	1.82	0.92	1.91	5.05	9.40	48.40
1949	8.32	3.23	4.03	3.59	4.91	1.11	2.79	2.92	3.79	2.58	1.88	4.84	43.99
1950	4.15	4.66	3.85	3.61	4.38	5.38	3.26	4.22	1.79	2.25	10.03	5.63	53.21
Av. 29 Yrs.	3.62	3.47	4.15	4.07	4.28	4.63	4.06	3.94	3.38	3.39	4.70	3.67	47.36

NORTH BRANFORD, CONN.—Elevation 220 feet
Record: January, 1928, to December, 1949

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	2.96	4.45	8.04	1.01	3.20	2.59	5.60	10.23	2.30	3.98	5.40	7.21	56.97
1943	2.44	1.91	3.98	2.59	4.71	3.88	4.18	1.35	1.12	4.73	4.17	1.65	36.71
1944	2.87	2.36	7.50	4.87	2.10	1.71	1.11	0.86	9.51	1.91	8.21	4.57	47.58
1945	2.13	3.79	2.61	4.85	5.80	2.55	2.95	4.32	2.97	2.42	5.72	6.05	46.16
1946	2.86	2.71	1.83	2.30	7.08	2.95	3.51	6.12	2.92	1.52	1.68	3.17	38.65
1947	2.77	2.17	2.76	5.09	4.59	3.54	4.60	3.31	4.85	2.55	9.78	3.63	49.64
1948	4.93	2.14	5.71	5.79	9.68	3.74	2.46	2.81	0.18	2.61	6.10	5.95	52.10
1949	7.50	3.52	3.56	3.86	6.68	0.11	3.69	3.34	5.31	2.59	2.17	3.31	45.64
1950	—	—	—	—	—	—	—	6.44	—	—	—	—	—
Av. 22 Yrs.	3.89	3.20	4.30	4.04	4.11	3.95	3.64	3.86	4.21	3.12	4.26	4.11	46.69

NORTH GUILFORD, CONN.—Elevation 280 feet
Record: January, 1931, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	2.89	4.43	8.29	0.53	2.94	2.99	5.22	9.49	2.17	4.24	5.65	7.52	56.36
1943	2.23	1.98	4.26	2.84	4.77	4.56	3.59	2.33	1.60	4.66	4.24	1.55	38.61
1944	2.57	2.66	7.69	5.01	0.94	2.14	1.02	0.88	10.11	1.82	8.92	4.10	47.86
1945	2.18	3.96	2.67	5.00	6.34	2.61	4.08	3.91	2.88	2.54	5.47	6.54	48.18
1946	2.09	2.90	1.85	2.18	6.47	3.52	4.24	6.46	2.68	1.42	1.76	3.50	39.07
1947	3.11	2.05	2.93	5.07	4.47	4.17	4.27	3.68	3.63	2.48	7.95	3.97	47.78
1948	4.73	2.37	5.62	5.54	9.16	3.96	2.90	2.72	0.32	2.98	6.42	5.38	52.10
1949	7.18	3.98	3.58	3.98	6.43	0.09	3.52	3.13	4.78	2.50	2.55	3.78	45.50
1950	3.97	3.33	3.80	3.15	4.90	3.80	3.12	6.35	1.00	1.46	4.75	5.44	45.07
Av. 20 Yrs.	3.96	3.05	4.43	4.02	4.19	4.01	3.68	4.26	4.42	3.93	4.41	4.28	47.74

NORWALK, CONN.—Elevation 116 feet
Record: January, 1892, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.75	2.48	8.02	1.77	4.86	2.91	6.76	9.32	2.79	2.79	5.44	5.61	57.50
1943	3.53	2.26	4.77	3.60	5.43	3.99	3.18	1.31	3.26	6.79	4.27	1.78	44.17
1944	3.76	2.26	8.50	5.50	1.69	3.27	0.86	1.52	10.00	1.84	6.04	3.81	49.05
1945	2.83	3.79	3.04	4.54	5.49	3.02	8.62	5.56	4.91	2.43	4.73	5.62	54.58
1946	1.96	2.22	2.38	1.75	10.78	3.49	4.60	5.84	5.91	0.94	1.97	2.24	44.08
1947	2.68	2.49	3.62	5.00	5.54	4.97	3.97	2.73	3.00	2.44	7.33	3.83	47.60
1948	4.44	1.87	3.76	4.53	8.11	5.84	3.57	2.86	1.04	1.84	5.02	7.21	49.89
1949	7.35	3.42	2.15	3.78	5.90	0.14	3.99	3.93	3.59	1.84	1.24	3.61	40.94
1950	3.00	3.62	2.97	2.30	4.53	3.24	6.14	4.81	1.81	2.02	5.08	5.23	44.75
Av. 59 Yrs.	3.61	3.45	4.07	3.66	4.08	3.40	4.10	4.63	3.95	3.48	3.63	3.73	45.78

NORWICH, CONN.—Elevation 150 feet
Record: January, 1871, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.88	2.39	7.77	0.58	2.02	2.49	4.23	4.16	1.22	4.69	4.88	7.59	46.90
1943	2.51	1.74	3.67	3.28	3.98	2.09	2.81	2.57	1.23	4.24	3.94	1.38	33.44
1944	1.40	1.93	5.78	3.77	1.22	2.89	0.89	0.56	10.34	1.81	8.08	3.03	41.70
1945	2.08	3.55	2.68	3.41	3.92	3.16	2.20	2.84	2.78	1.40	5.35	4.57	37.94
1946	3.15	3.28	1.77	1.94	5.10	3.27	3.95	6.96	2.51	0.36	1.03	2.99	36.31
1947	2.60	1.25	3.33	5.66	1.62	3.15	4.48	2.14	2.96	2.95	4.79	3.05	37.98
1948	3.66	2.19	4.87	4.09	7.85	2.33	2.96	1.40	0.73	2.58	5.70	2.86	41.22
1949	5.47	2.54	1.67	3.60	3.21	0.02	1.08	7.77	1.64	2.06	2.43	2.39	33.88
1950	3.17	4.18	3.16	2.54	5.42	1.96	2.26	5.76	1.36	2.01	4.70	2.80	39.32
Av. 80 Yrs.	3.76	3.30	4.02	3.66	3.24	3.03	3.49	4.28	3.33	3.42	3.74	3.65	42.92

NORTH STAMFORD, CONN.—Elevation 200 feet
Record: January, 1911, to July, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.77	2.16	7.29	1.37	4.07	2.96	5.45	8.14	3.22	4.14	2.92	5.33	50.82
1943	3.39	2.10	3.99	3.39	5.23	3.67	3.61	1.62	2.98	6.03	3.41	1.39	40.81
1944	2.98	1.99	7.82	4.34	1.92	3.94	0.84	1.74	9.10	1.80	5.16	4.26	45.89
1945	2.27	3.74	2.63	4.06	5.23	2.49	8.19	5.42	4.68	2.16	4.32	5.78	50.97
1946	2.11	2.55	2.58	1.73	8.53	3.48	4.35	4.75	6.66	1.02	1.86	2.28	41.90
1947	2.75	3.22	4.04	5.56	5.18	4.79	4.68	1.66	3.02	2.06	7.45	4.49	48.90
1948	4.38	1.95	5.57	3.59	8.26	5.91	4.47	4.08	0.23	2.28	4.91	6.29	51.92
1949	7.25	3.08	3.80	4.19	5.99	0.12	3.34	3.71	3.44	1.79	1.16	3.40	41.27
1950	2.84	4.24	3.20	2.22	4.26	3.00	3.99	—	—	—	—	—	—
Av. 39 Yrs.	3.34	2.87	3.86	3.65	3.95	3.63	3.95	4.49	3.91	3.50	3.30	3.26	43.71

PEOPLES FOREST RANGER STATION, CONN.
Record: February, 1943, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1943	—	1.98	3.04	3.55	6.39	3.12	2.15	1.06	2.07	5.30	4.59	0.80	—
1944	1.65	2.20	4.89	4.66	2.32	3.58	3.15	3.67	7.27	—	6.32	3.79	—
1945	3.89	3.95	2.07	5.53	7.04	5.70	6.49	5.35	3.52	2.67	4.99	4.64	55.81
1946	2.52	2.81	1.62	2.58	5.51	3.19	5.96	4.04	3.94	2.04	1.04	2.60	37.85
1947	2.59	2.56	3.49	4.23	5.31	3.34	4.90	1.55	3.26	2.24	6.54	2.87	42.88
1948	2.97	1.89	3.21	3.17	6.31	6.50	2.64	1.20	0.63	1.78	4.79	7.53	42.62
1949	6.55	2.47	3.06	3.57	5.95	1.17	3.58	2.65	2.59	2.38	1.48	3.16	38.61
1950	4.30	4.07	3.09	2.69	3.78	5.97	2.58	3.52	1.70	1.92	8.14	4.98	46.72
Av. 6 Yrs.	3.80	2.96	2.76	3.62	5.65	4.31	4.36	3.05	2.61	2.17	4.50	4.30	44.09

PROSPECT, CONN. (New Haven Water Co.)—Elevation 425 feet
Record: May, 1915, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.64	4.63	7.83	0.62	4.36	2.91	4.18	5.09	3.68	3.39	5.66	7.55	53.54
1943	2.68	2.62	4.61	3.10	5.51	3.66	2.89	2.04	1.57	6.77	4.80	1.31	41.56
1944	2.25	2.96	6.20	4.68	1.43	2.67	5.10	2.33	8.99	2.10	6.56	4.69	49.96
1945	2.86	3.84	2.59	6.04	7.32	2.82	5.91	3.84	4.33	2.26	6.84	7.44	56.09
1946	1.97	2.84	1.81	2.12	7.13	3.47	6.02	8.02	3.47	1.69	1.83	2.22	42.59
1947	3.20	3.06	3.19	4.28	4.91	5.20	6.66	3.61	2.16	1.49	8.13	3.74	49.63
1948	3.16	2.48	4.76	5.28	5.92	5.09	2.93	2.86	0.35	2.34	6.47	7.39	49.03
1949	7.13	2.67	3.35	5.30	5.50	0.57	3.00	2.74	3.90	1.93	2.15	3.70	41.94
1950	3.31	3.40	3.67	3.56	4.52	3.50	4.49	4.46	1.11	2.57	6.01	5.67	46.27
Av. 35 Yrs.	3.56	3.02	4.00	4.11	4.36	4.06	4.61	4.13	4.02	3.36	4.37	3.98	47.58

PUTNAM, CONN.—Elevation 458 feet
Record: November, 1936, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1936	—	—	—	—	—	—	—	—	—	—	1.40	8.28	—
1937	4.65	2.16	3.41	3.34	2.37	3.14	4.07	7.06	4.81	3.37	5.14	2.54	46.06
1938	5.55	3.02	1.54	2.25	3.75	7.19	11.32	5.04	3.07	3.98	3.48	3.61	53.80
1939	2.93	2.79	3.30	5.18	1.03	3.21	2.08	6.36	2.41	5.43	0.80	3.76	39.28
1940	3.00	1.93	4.02	5.64	5.29	2.65	5.74	1.17	2.75	1.64	6.52	1.92	42.27
1941	1.71	1.51	1.51	1.06	3.48	4.48	5.10	2.21	1.80	2.18	3.04	2.63	30.71
1942	4.24	3.49	6.66	0.99	2.59	4.28	5.19	5.70	1.64	4.17	6.39	7.71	53.05
1943	2.51	1.69	3.85	3.62	4.63	1.47	4.57	1.02	0.47	4.88	4.00	1.11	33.82
1944	1.32	2.51	4.35	4.53	1.33	4.34	1.11	1.41	9.06	2.19	6.21	2.65	41.01
1945	2.36	3.54	2.21	4.33	5.23	5.11	3.69	3.41	1.63	2.28	6.28	5.60	45.67
1946	2.27	2.47	1.81	2.42	5.96	3.29	3.15	8.16	3.19	0.65	1.60	3.66	38.63
1947	2.99	1.73	2.81	4.66	3.46	3.97	4.67	2.68	4.77	2.29	5.00	3.08	42.11
1948	4.98	1.94	4.59	4.28	6.76	5.09	3.92	2.20	1.21	2.61	6.44	3.03	47.05
1949	4.55	3.41	3.02	2.89	5.43	0.23	1.08	5.17	5.07	2.35	2.98	3.12	39.30
1950	4.78	4.37	3.44	5.06	4.62	3.14	3.66	7.06	2.37	1.85	8.91	3.81	53.07
Av. 14 Yrs.	3.42	2.61	3.32	3.59	4.00	3.68	4.24	4.19	3.16	2.85	4.77	3.44	43.27

PUTNAM HEIGHTS, CONN.
Record: June, 1940, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	—	—	—	—	—	4.35	4.71	0.90	2.40	1.67	6.30	2.44	—
1941	2.00	2.27	1.81	1.19	2.74	3.82	5.62	2.92	0.96	1.84	3.13	2.78	31.08
1942	4.02	2.03	8.00	0.72	2.21	4.97	4.91	4.20	1.77	3.98	5.83	6.80	49.44
1943	2.70	1.68	3.81	3.80	4.03	1.60	3.22	0.96	0.33	5.26	3.65	1.01	32.05
1944	1.14	2.03	4.46	4.70	1.10	3.52	0.56	1.29	9.30	1.98	6.00	2.85	38.93
1945	2.59	3.50	2.47	3.43	5.29	5.35	3.11	3.83	1.64	2.14	5.20	5.02	43.57
1946	3.23	2.64	1.98	2.19	4.91	3.17	2.65	6.75	4.28	0.44	1.26	3.14	36.64
1947	2.73	1.65	2.58	4.34	3.13	3.97	3.67	1.77	5.63	1.98	4.10	2.13	37.68
1948	3.27	1.60	3.64	3.70	6.56	4.61	3.96	2.22	0.93	2.63	5.58	2.76	41.46
1949	4.98	2.43	2.00	2.84	4.37	0.85	0.83	6.38	4.22	2.35	1.86	2.58	35.69
1950	3.77	3.67	2.76	4.32	3.29	2.82	1.94	6.24	1.40	1.68	5.62	3.27	40.78
Av. 10 Yrs.	3.04	2.35	3.35	3.12	3.76	3.47	3.05	3.66	3.05	2.43	4.22	3.23	38.74

PUTNAM LAKE, CONN. (Greenwich)—Elevation 300 feet
Record: 1885 to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	2.55	3.42	7.36	1.29	3.54	2.39	5.69	8.02	3.22	2.94	3.53	5.00	48.95
1943	3.00	1.11	3.98	2.54	4.66	3.24	3.18	1.74	2.55	7.78	2.94	1.44	38.16
1944	2.73	2.25	7.41	4.56	2.02	2.93	0.64	1.33	10.24	2.44	5.50	3.93	45.98
1945	2.78	2.89	2.14	4.35	5.51	3.00	8.91	5.22	3.69	2.01	4.32	4.70	49.52
1946	1.71	1.56	2.74	1.27	9.58	3.76	4.96	4.58	6.23	0.92	1.24	2.20	40.75
1947	2.68	2.97	3.61	4.33	5.75	3.91	4.30	1.45	3.44	1.68	7.23	4.88	46.23
1948	3.98	1.48	3.37	4.25	7.45	5.39	2.96	3.07	0.43	3.06	4.26	5.48	45.18
1949	6.11	2.75	2.48	4.47	5.50	0.20	3.36	4.59	3.64	1.70	0.97	2.93	38.70
1950	2.68	3.53	3.30	1.86	3.67	2.90	3.64	4.21	1.26	2.15	6.19	4.43	39.82
Av. 65 Yrs.	3.50	3.17	3.65	3.46	3.79	3.35	4.05	4.40	3.68	3.16	3.45	3.46	43.42

ROCKVILLE, CONN.
Record: July, 1942, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	—	—	—	—	—	—	4.95	2.39	2.92	3.43	6.52	5.49	—
1943	2.46	1.88	3.46	3.38	Inc.	3.67	3.28	1.16	0.79	4.31	4.62	0.84	—
1944	1.49	1.77	3.52	3.88	1.94	7.48	2.55	2.39	7.36	2.21	5.65	2.90	43.14
1945	2.42	2.94	2.27	4.33	5.60	4.64	4.86	2.86	1.18	2.15	4.25	4.92	42.42
1946	2.44	2.30	1.46	2.34	5.10	2.79	3.98	4.26	2.68	0.89	1.55	2.24	32.03
1947	2.09	1.80	2.03	3.81	2.34	3.72	7.00	1.75	2.65	1.77	4.37	1.72	34.95
1948	2.56	0.98	2.48	2.93	5.53	6.48	2.51	1.75	0.23	1.46	5.53	3.70	36.14
1949	4.12	2.51	1.70	3.09	—	0.42	2.28	2.02	1.76	1.94	3.00	—	—
1950	3.65	3.04	3.28	3.44	3.39	4.33	2.22	7.09	1.30	1.47	4.39	3.75	41.35
Av. 6 Yrs.	2.44	2.14	2.51	3.45	3.97	4.91	3.85	3.35	2.57	1.66	4.29	3.20	38.34

ROCKWOOD LAKE, CONN. (Greenwich Water Co.)
Record: January, 1941, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	2.26	2.55	1.13	2.05	2.75	3.93	4.47	3.97	0.58	1.72	3.13	3.91	32.45
1942	2.41	3.41	7.19	1.27	3.45	2.25	5.06	8.16	2.83	2.99	3.52	5.01	47.55
1943	2.97	1.11	3.32	2.58	4.66	3.03	3.01	1.59	1.99	6.59	2.79	0.17	33.81
1944	2.38	1.99	7.08	3.92	2.03	3.21	0.71	1.33	7.91	2.40	5.40	3.69	42.05
1945	2.48	2.75	2.41	4.72	5.72	2.83	8.55	6.16	3.79	2.19	4.46	1.84	47.90
1946	1.50	1.50	2.70	1.31	9.52	3.64	4.79	4.73	5.82	0.90	1.09	1.74	39.24
1947	2.59	2.98	3.56	3.99	5.81	3.79	4.06	1.84	3.02	1.50	7.18	4.88	45.20
1948	3.84	1.58	3.43	4.51	7.26	5.62	3.19	3.19	0.34	2.22	3.84	5.02	44.04
1949	6.22	2.69	2.33	4.34	5.04	0.11	3.13	3.45	3.46	1.50	0.86	2.71	35.84
1950	2.54	4.13	2.69	1.95	3.49	2.78	3.84	3.79	1.04	1.53	5.49	3.97	37.15
Av. 10 Yrs.	2.92	2.47	3.58	3.06	4.98	3.12	4.08	3.82	3.08	2.35	3.77	3.29	40.52

ROCKY RIVER DAM, CONN.
Record: March, 1941, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	—	—	1.34	0.94	2.14	5.08	7.06	3.88	1.58	2.19	3.67	4.25	—
1942	2.21	3.17	1.84	1.10	3.95	3.92	4.73	4.09	3.12	3.37	5.99	5.08	42.57
1943	3.36	1.74	3.07	2.87	6.17	4.47	3.44	2.89	1.30	5.26	5.15	0.95	40.67
1944	1.90	1.93	4.89	4.80	2.16	4.33	4.56	1.69	5.24	1.91	4.59	3.98	41.98
1945	3.35	3.62	2.45	5.10	6.89	5.87	7.27	4.86	2.58	2.01	4.37	4.99	53.36
1946	1.86	2.44	2.57	1.87	6.32	3.58	6.09	3.71	4.32	1.75	1.45	2.26	38.22
1947	2.46	1.64	3.57	3.95	5.76	4.90	3.29	2.19	2.79	2.28	6.96	2.01	41.80
1948	2.97	1.81	3.74	4.49	7.16	5.62	2.82	1.55	0.16	1.15	4.04	6.25	41.76
1949	6.47	2.75	2.81	3.50	7.22	1.07	3.68	1.50	2.48	2.19	1.19	3.81	38.57
1950	3.64	3.65	3.12	1.66	4.45	3.91	4.44	6.02	1.59	1.51	—	4.79	—
Av. 8 Yrs.	3.07	2.39	3.12	3.46	5.70	4.22	4.49	2.81	2.75	2.49	4.22	3.67	42.39

ROUND POND, CONN.
Record: June, 1940, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	—	—	—	—	—	4.29	3.15	—	2.99	2.46	5.31	2.44	—
1941	2.71	3.22	2.43	1.62	2.37	3.88	9.00	3.30	0.30	2.48	3.57	5.55	40.43
1942	2.86	3.50	7.04	1.11	4.64	4.07	5.61	9.07	4.16	3.51	4.73	4.68	54.98
1943	3.16	1.90	4.55	4.14	5.65	4.01	4.71	2.91	1.85	7.55	4.52	0.93	45.88
1944	2.79	2.22	5.86	4.99	2.50	3.59	2.24	1.58	8.86	1.94	6.62	3.85	47.04
1945	3.39	4.06	1.88	4.94	6.72	4.00	8.85	4.03	3.37	2.53	4.51	5.52	53.80
1946	2.27	2.23	2.36	1.52	8.30	3.17	5.12	6.17	6.60	1.68	1.27	1.11	41.80
1947	1.99	2.84	4.43	4.18	7.63	4.43	3.85	8.10	4.03	1.68	9.31	3.95	56.42
1948	4.79	2.33	4.80	4.35	6.83	4.08	7.15	1.76	0.82	2.33	4.84	6.90	50.98
1949	5.77	2.22	2.23	4.12	6.14	0.45	2.92	5.10	3.46	1.84	1.20	3.83	39.28
1950	2.94	3.88	4.06	2.17	4.06	3.51	6.65	3.52	1.65	1.28	8.23	5.70	47.65
Av. 10 Yrs.	3.27	2.84	3.96	3.31	5.48	3.52	5.61	4.55	3.51	2.68	4.88	4.20	47.81

SALISBURY, CONN.—Elevation 1,015 feet
Record: January, 1934, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1934	3.78	2.32	2.68	3.89	5.38	3.83	3.43	4.57	8.41	2.63	5.33	2.85	49.10
1935	4.26	2.99	2.18	1.57	1.90	5.55	5.35	2.13	3.00	1.05	3.68	1.24	34.90
1936	5.82	2.15	7.33	4.01	3.59	1.86	2.89	4.59	2.99	4.41	1.54	5.62	46.80
1937	6.11	2.37	4.06	2.99	4.84	9.75	3.46	4.75	6.09	5.87	2.93	2.45	55.67
1938	3.61	2.61	1.12	2.80	3.81	9.64	6.74	4.13	12.06	1.77	3.46	3.45	55.20
1939	2.63	3.65	3.14	4.73	1.11	2.88	1.12	4.62	2.78	5.03	1.80	2.17	35.66
1940	1.74	2.10	5.92	5.06	5.63	4.28	3.56	4.06	5.19	2.26	4.96	2.96	47.72
1941	2.95	1.63	2.66	1.15	4.04	5.37	6.48	2.15	1.48	2.87	2.73	3.57	37.08
1942	2.10	1.42	6.39	1.07	5.16	6.20	8.28	3.30	4.49	3.74	6.87	5.85	54.87
1943	3.17	1.38	2.41	2.74	4.85	2.65	5.82	2.18	1.42	5.62	5.92	0.78	38.94
1944	0.79	3.22	4.23	3.35	2.77	6.10	2.60	4.81	3.43	2.06	4.66	2.24	40.26
1945	4.60	2.95	2.92	5.24	7.05	6.92	10.10	4.60	4.81	2.99	4.44	4.07	60.69
1946	2.18	2.73	1.54	2.76	5.15	3.36	4.68	2.09	4.38	2.12	1.01	1.43	33.43
1947	3.87	2.10	3.15	4.05	4.79	3.57	4.98	1.28	2.49	2.34	5.42	1.82	39.86
1948	2.38	1.96	4.26	3.78	5.65	6.36	2.83	1.89	1.34	1.52	—	9.18	—
1949	3.74	2.53	1.54	3.34	5.88	1.19	3.97	3.03	2.56	2.98	1.13	3.88	35.77
1950	4.04	3.13	1.80	2.38	3.79	4.01	2.84	4.27	2.05	1.61	6.51	3.14	39.57
Av. 16 Yrs.	3.46	2.45	3.32	3.19	4.36	4.82	4.77	3.53	4.24	3.08	3.90	2.97	44.09

SAUGATUCK RESERVOIR, CONN.
Record: April, 1943, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1943	—	—	—	3.40	5.75	4.56	3.21	1.74	2.98	6.05	4.99	1.15	—
1944	2.58	2.24	7.99	4.41	1.53	2.37	0.47	2.63	9.43	1.75	6.14	3.35	44.89
1945	—	—	—	—	—	—	6.54	3.73	3.79	—	5.36	—	—
1946	2.21	2.22	2.00	1.93	7.86	3.51	4.88	4.43	4.60	1.53	1.34	2.36	38.87
1947	2.31	2.04	4.26	4.42	5.34	4.32	4.16	4.15	4.19	1.76	7.84	3.68	48.47
1948	4.21	1.58	4.54	5.60	7.05	5.02	4.43	1.88	1.02	—	6.13	6.71	—
1949	5.79	3.09	2.19	4.22	5.61	0.29	2.80	3.77	3.84	1.98	1.45	2.94	37.97
1950	3.01	3.52	3.36	2.80	4.38	—	4.45	3.70	1.32	—	5.42	5.05	—
Av. 4 Yrs.	3.22	2.40	4.11	3.75	5.09	2.62	3.08	3.74	5.52	1.76	4.19	3.08	42.56

SHELTON, CONN. (Derby)—Elevation 50 feet
Record: January, 1896, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	—	—	8.30	0.65	3.40	3.02	5.75	8.75	2.83	3.60	5.33	—	—
1943	3.04	2.26	—	—	—	—	—	—	—	—	—	—	—
1944	3.14	2.26	8.68	4.63	1.37	1.85	0.33	1.27	11.63	2.10	6.12	—	—
1945	—	—	—	—	—	—	—	—	—	—	—	—	—
1946	—	—	—	—	—	—	—	—	—	—	—	2.57	—
1947	2.75	2.36	3.75	4.30	4.51	4.61	3.42	4.10	2.88	3.42	7.88	3.81	47.79
1948	4.29	1.74	5.10	5.29	7.82	4.48	3.29	3.10	0.31	1.73	6.36	6.82	50.33
1949	7.53	2.78	3.44	4.67	5.94	—	—	—	—	—	—	—	—
1950	3.58	3.95	—	3.23	4.68	4.98	4.18	5.43	1.13	2.02	5.43	4.89	—
Av. 47 Yrs.	3.98	3.64	4.48	4.18	4.03	3.80	4.17	4.33	3.80	3.74	4.04	4.24	48.43

SHEPAUG DAM, CONN.
Record: January, 1941, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	1.47	Inc.	Inc.	0.95	2.19	5.15	5.00	3.89	0.99	2.52	3.06	3.60	—
1942	3.78	1.80	6.11	1.11	5.04	6.10	5.38	2.96	3.18	3.09	6.24	—	—
1943	4.01	2.06	2.97	3.49	7.43	3.35	3.51	1.68	1.54	4.91	6.58	0.95	42.48
1944	—	—	5.09	4.14	1.30	4.73	4.47	1.67	5.66	1.88	5.67	3.53	—
1945	3.85	Inc.	Inc.	5.37	7.06	6.02	6.16	4.88	2.09	2.79	5.43	5.22	—
1946	2.01	2.61	2.19	2.31	5.14	3.37	6.44	3.63	4.78	1.98	1.47	2.64	38.57
1947	2.88	3.45	3.45	4.51	4.15	3.84	5.49	1.92	2.61	1.15	6.39	3.93	43.68
1948	3.60	1.95	3.70	4.17	7.77	7.37	3.05	1.89	—	1.25	4.55	10.26	—
1949	6.00	3.33	2.26	3.74	5.92	0.91	3.50	3.19	3.26	2.46	1.54	5.94	42.05
1950	—	—	3.29	2.82	4.13	8.65	3.17	4.87	1.73	1.73	7.32	5.20	—
Av. 4 Yrs.	3.72	2.86	2.73	3.51	5.66	2.87	4.74	2.60	3.05	2.62	3.97	3.36	41.69

SHUTTLE MEADOW RESERVOIR, CONN. (New Britain)—Elevation 374 feet
Record: January, 1929, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.96	4.55	7.36	0.67	4.56	4.91	3.37	6.66	3.84	3.15	6.89	7.44	37.38
1943	3.41	1.99	4.17	2.58	5.79	4.64	2.96	1.70	0.73	6.02	4.34	1.00	39.33
1944	2.13	2.13	5.30	5.22	1.67	2.64	2.78	2.29	9.36	2.75	7.32	4.51	48.00
1945	—	—	—	—	—	—	3.96	4.36	3.38	—	6.33	6.42	—
1946	2.65	2.68	1.90	2.68	6.67	3.52	4.29	8.69	2.71	1.72	1.38	3.17	42.06
1947	2.80	2.60	2.77	4.66	4.48	5.62	5.56	2.18	3.62	2.76	6.53	2.82	46.40
1948	4.97	2.32	4.02	4.28	6.11	6.28	2.80	2.68	0.28	2.20	6.26	5.46	47.66
1949	6.65	2.80	2.89	4.75	5.14	0.55	3.86	4.97	3.72	2.18	2.25	3.17	42.88
1950	4.01	4.45	3.16	2.73	3.52	3.23	3.59	4.30	1.55	2.10	6.05	4.67	43.36
Av. 21 Yrs.	4.06	3.15	4.14	4.01	4.02	4.15	3.42	4.05	3.95	3.08	4.25	3.70	45.98

STEVENSON DAM, CONN.
Record: January, 1943, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1943	2.10	2.54	3.98	3.03	4.80	5.03	3.14	Inc.	2.59	5.70	5.05	1.31	—
1944	2.79	2.49	6.56	5.00	1.75	1.99	2.05	2.03	9.19	1.73	5.30	4.39	45.27
1945	—	3.71	2.52	5.66	6.27	4.71	9.10	3.23	2.88	2.57	6.61	5.59	—
1946	3.07	2.68	1.89	2.01	7.74	2.87	4.93	5.96	4.53	2.34	1.65	2.89	42.56
1947	2.49	2.33	3.62	4.40	4.84	5.50	6.10	3.20	2.84	3.38	9.55	3.44	51.74
1948	3.96	1.34	5.22	5.09	6.52	4.58	2.47	1.81	0.17	1.51	6.39	6.99	46.05
1949	7.34	2.75	3.23	5.41	5.58	0.34	3.97	1.57	4.71	1.70	1.79	3.52	41.91
1950	3.70	3.89	4.27	3.32	4.59	3.65	5.43	4.79	1.26	2.28	6.67	5.94	49.79
Av. 6 Yrs.	3.89	2.58	4.13	4.20	5.17	3.15	4.16	3.23	3.78	2.16	5.23	4.54	46.22

STORRS, CONN. (Mansfield)—Elevation 640 feet
Record: January, 1893, to September, 1920; March, 1922, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.30	1.94	7.84	0.71	2.72	3.73	4.58	4.71	2.24	3.47	6.35	5.61	47.20
1943	2.69	1.75	3.52	3.84	4.77	2.15	3.65	1.66	0.58	5.41	4.02	0.86	34.90
1944	1.48	2.36	4.58	4.66	2.20	4.50	1.90	1.36	9.15	2.07	6.23	2.64	43.07
1945	2.65	3.10	2.24	5.44	5.75	4.62	3.76	3.13	1.74	2.37	5.23	5.45	45.48
1946	2.50	2.34	1.81	2.39	5.35	2.94	4.03	8.34	3.17	0.36	1.46	3.28	37.97
1947	2.59	1.67	2.44	4.66	2.70	3.57	5.00	3.11	4.62	2.32	5.72	2.26	40.68
1948	3.34	1.82	4.26	4.03	6.13	5.61	2.95	1.85	0.53	2.49	5.73	3.52	42.26
1949	4.37	2.76	1.52	3.90	4.45	0.83	1.78	5.24	3.00	2.48	2.30	2.65	35.28
1950	3.71	3.58	3.17	2.98	4.37	3.45	3.18	5.59	1.22	2.14	5.09	4.55	43.03
Av. 55 Yrs.	3.49	3.21	3.96	3.60	3.58	3.19	4.01	4.10	3.64	3.32	3.65	3.60	43.35

THOMPSONVILLE, CONN. (Formerly Enfield)—Elevation 50 feet
Record: April, 1915, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	2.49	2.58	8.08	0.63	4.55	3.29	6.37	3.49	4.93	3.11	6.75	6.38	52.65
1943	2.18	1.71	3.54	3.42	5.84	4.12	3.88	0.77	1.24	5.10	5.05	0.77	37.62
1944	1.55	1.88	4.88	4.51	1.58	4.78	1.08	2.95	5.66	2.44	4.09	2.98	38.38
1945	3.16	4.05	2.18	4.20	6.89	6.87	6.13	4.24	1.90	2.25	4.54	4.80	51.21
1946	2.00	2.17	1.83	2.38	5.35	2.67	4.76	5.24	1.92	1.32	0.90	2.80	33.34
1947	2.74	1.65	3.50	4.22	4.68	2.99	—	2.79	4.22	2.52	5.57	1.61	—
1948	2.52	1.31	3.40	3.38	5.43	5.70	3.97	2.87	1.32	1.13	5.94	2.82	39.79
1949	4.87	2.64	1.87	3.10	5.41	0.39	2.50	2.56	2.66	2.06	2.12	3.05	33.23
1950	4.31	—	2.84	3.29	3.39	4.07	2.71	—	2.94	2.03	—	4.21	—
Av. 33 Yrs.	3.08	2.37	3.31	3.26	3.67	4.17	3.83	3.49	3.71	2.62	3.54	2.93	39.98

TORRINGTON, CONN. (Torrington No. 1)—Elevation 600 feet
Record: January, 1920, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1939	4.33	4.41	4.05	4.72	2.11	3.37	2.09	7.96	1.72	—	2.00	—	—
1940	3.12	3.30	5.53	5.47	5.29	3.21	2.23	3.51	2.36	3.14	—	—	—
1941	—	—	1.83	0.70	2.88	4.82	8.20	3.81	0.65	2.19	3.34	4.02	—
1942	4.15	2.21	7.09	0.55	5.95	6.05	6.33	2.43	3.44	4.31	7.02	6.20	55.73
1943	3.38	Inc.	3.57	Inc.	Inc.	2.68	2.24	Inc.	2.51	4.64	5.23	0.97	—
1944	1.29	2.27	5.13	4.38	1.74	4.11	3.03	4.21	7.44	2.28	6.71	3.12	45.71
1945	4.64	4.33	2.19	5.66	6.30	6.29	7.95	5.54	2.24	2.44	4.73	—	—
1946	2.40	2.74	1.71	1.90	4.66	3.22	6.36	Inc.	4.39	1.30	0.90	2.38	—
1947	2.65	3.50	3.50	2.59	3.50	2.78	—	1.77	2.18	1.76	7.40	3.19	—
1948	3.79	1.96	3.32	3.60	5.86	7.02	2.88	1.38	1.15	1.37	4.95	10.91	48.19
1949	6.40	—	4.86	2.97	6.15	1.02	2.39	3.23	2.78	2.46	1.40	4.81	—
1950	4.66	3.17	3.50	2.39	3.66	6.62	2.61	3.90	1.38	1.55	7.90	4.90	46.24
Av. 23 Yrs.	4.02	3.15	3.93	3.65	3.84	4.39	4.18	3.88	4.53	3.04	4.15	3.85	46.61

TORRINGTON, CONN. (Torrington No. 2)
Record: April, 1941, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	—	—	—	0.63	3.06	5.50	7.74	3.77	1.10	2.41	3.39	3.78	—
1942	2.69	3.85	7.95	0.93	6.12	5.59	5.69	2.76	3.54	3.84	6.64	6.76	56.36
1943	3.66	1.59	2.55	3.56	7.84	2.97	2.61	1.65	—	—	5.08	0.95	—
1944	1.10	2.41	5.14	4.79	1.81	4.17	3.12	4.01	8.47	2.62	6.43	4.12	48.19
1945	4.88	4.78	2.54	6.00	6.93	7.15	8.63	6.15	2.50	2.44	—	5.59	—
1946	2.86	2.62	1.90	2.58	—	2.58	7.07	5.24	4.51	—	1.04	2.20	—
1947	1.88	3.15	3.45	3.69	4.59	3.24	6.14	1.81	2.06	1.42	5.46	3.55	40.44
1948	3.70	2.02	3.75	3.57	7.30	6.16	2.59	1.28	0.47	—	4.87	9.00	—
1949	—	2.17	4.30	3.25	6.59	1.01	2.58	3.10	2.83	2.39	1.75	4.58	—
1950	4.55	3.53	—	—	3.77	5.80	2.35	3.88	1.16	1.35	7.94	4.81	—
Av. 3 Yrs.	1.89	3.14	5.51	3.14	4.17	4.33	4.33	4.98	2.86	4.69	6.18	4.81	48.33

TRAP FALLS RESERVOIR, CONN. (Shelton)—Elevation 353 feet
Record: 1922 to 1927; August, 1930, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	5.36	2.44	8.81	1.15	2.91	4.83	6.39	10.27	3.06	3.57	5.85	5.75	60.39
1943	3.46	1.87	4.61	3.74	5.62	3.95	Inc.	Inc.	2.58	5.93	4.55	1.72	—
1944	2.77	2.04	8.68	4.99	1.68	1.63	0.51	0.96	11.39	1.86	6.84	3.51	46.96
1945	2.78	3.78	2.54	5.57	6.46	3.58	8.04	4.52	3.60	2.16	6.97	6.66	56.66
1946	2.27	2.52	1.73	2.03	7.61	3.25	4.28	5.48	4.05	0.89	1.69	2.94	38.74
1947	2.51	2.27	3.65	5.34	5.32	4.55	3.67	3.67	2.71	3.87	7.46	3.48	48.50
1948	4.14	2.07	4.57	5.46	7.94	4.56	4.20	2.96	1.07	1.87	6.27	7.84	52.95
1949	7.44	3.14	2.40	3.89	6.62	0.28	2.76	4.27	4.23	2.12	1.48	2.73	41.36
1950	3.31	—	2.63	2.93	4.14	—	4.18	5.68	1.35	2.71	6.30	4.68	—
Av. 18 Yrs.	3.70	2.92	4.12	4.15	4.27	3.38	4.08	4.67	4.20	2.97	3.90	3.92	46.28

WATERBURY, CONN.—Elevation 400 feet
Record: January, 1887, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.80	2.71	8.05	0.66	3.81	3.44	3.84	5.74	3.09	2.76	5.91	5.54	49.35
1943	2.68	1.41	3.08	2.48	4.63	3.90	2.68	1.58	1.36	5.83	4.71	0.80	35.14
1944	0.84	1.37	4.86	4.92	1.56	2.43	3.24	1.25	9.04	1.67	7.29	3.81	42.28
1945	3.60	2.35	2.46	4.72	6.76	3.72	6.18	4.43	3.20	1.97	5.85	5.69	50.93
1946	2.11	2.33	1.75	2.01	7.09	3.27	3.85	5.85	4.46	1.30	1.80	2.54	38.27
1947	2.12	2.63	3.28	3.54	4.24	4.95	5.47	3.70	3.52	1.11	7.16	3.26	45.01
1948	3.74	1.68	3.54	4.55	6.32	5.49	3.90	3.20	0.68	1.11	6.88	8.74	49.83
1949	6.14	1.93	1.72	4.12	5.37	0.89	4.75	3.24	4.18	2.43	1.66	3.21	39.64
1950	3.18	3.41	2.71	3.21	3.71	3.99	4.27	3.78	0.89	1.82	6.17	3.52	40.66
Av. 64 Yrs.	3.83	3.57	3.99	3.65	3.91	3.55	4.35	4.26	3.75	3.47	3.76	3.85	45.94

WATERBURY, CONN. (Waterbury #2)—Elevation 333 feet
Record: January, 1924, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	4.49	2.30	7.53	0.73	4.09	3.68	4.03	5.62	3.24	2.74	6.09	6.07	50.61
1943	3.37	2.28	3.73	3.20	5.71	3.64	2.80	1.21	1.43	6.76	4.79	0.97	39.89
1944	—	—	5.13	4.50	1.77	2.35	3.26	1.11	9.91	1.72	7.11	4.66	—
1945	3.32	Inc.	Inc.	4.72	6.42	3.72	6.16	4.43	3.56	1.98	5.72	5.89	—
1946	2.22	2.45	1.85	1.89	6.81	3.35	3.96	5.63	5.09	1.24	1.76	2.64	38.89
1947	1.96	2.69	3.23	5.06	3.14	4.97	4.69	2.85	2.86	0.94	6.74	3.25	42.38
1948	3.29	2.04	3.69	4.16	5.01	5.26	3.25	3.15	0.71	1.75	5.97	10.23	48.51
1949	5.47	3.61	2.51	3.86	5.59	0.76	3.85	2.85	3.86	2.25	1.49	3.38	39.48
1950	—	—	3.46	3.42	—	2.66	4.25	3.92	0.93	1.38	7.05	5.39	—
Av. 24 Yrs.	3.79	3.14	3.80	3.52	3.88	3.67	3.68	4.16	3.69	2.93	3.98	3.55	43.79

WEPAWAUG RESERVOIR, CONN. (Orange)—Elevation 190 feet
Record: November, 1913, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	2.41	4.11	8.35	1.09	4.02	2.85	5.65	8.66	2.44	3.38	4.92	5.84	53.72
1943	2.65	2.06	5.43	3.29	4.97	3.53	3.68	1.36	1.70	5.27	4.38	1.56	39.88
1944	2.68	1.90	8.38	4.61	1.04	1.37	0.54	1.26	11.15	1.87	5.65	4.22	44.67
1945	2.11	3.70	2.21	3.73	6.48	2.29	5.91	3.81	3.36	2.34	5.48	6.00	47.42
1946	2.43	2.68	1.63	1.85	6.16	3.20	3.54	6.41	3.90	1.62	1.71	2.64	37.77
1947	2.91	2.73	3.95	4.04	4.39	4.33	5.46	2.78	2.67	3.24	7.76	2.74	47.00
1948	4.61	2.82	5.22	5.57	7.83	4.44	4.03	3.14	0.23	2.29	7.11	7.00	54.29
1949	6.53	3.17	3.24	4.51	7.71	0.18	3.17	2.61	4.85	1.93	2.17	3.18	43.25
1950	3.20	2.99	3.46	3.46	4.48	4.01	4.30	6.40	1.28	2.12	4.71	4.39	44.80
Av. 37 Yrs.	3.72	3.22	3.94	3.92	4.00	3.98	3.90	4.23	3.65	3.26	3.96	3.87	45.85

WESTBROOK, CONN.
Record: January, 1941, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	3.10	1.87	3.19	1.30	2.44	4.35	5.06	2.60	0.07	2.79	3.65	3.82	34.24
1942	3.30	3.98	7.21	1.01	2.95	2.94	5.39	6.67	1.93	3.63	5.58	6.70	51.29
1943	3.66	2.09	3.20	3.65	4.52	3.54	3.06	1.68	0.74	4.75	3.62	1.90	36.41
1944	2.92	2.09	6.46	4.96	1.16	2.58	1.15	1.13	8.08	2.26	9.62	3.21	45.62
1945	2.32	3.04	2.63	4.61	4.72	4.76	2.28	4.82	2.68	2.56	5.28	5.64	45.34
1946	3.48	3.08	1.95	2.13	7.03	3.01	2.28	6.52	2.92	0.95	1.48	2.88	37.71
1947	3.13	1.32	2.34	5.34	4.75	2.56	3.15	7.46	2.72	2.44	8.27	2.69	46.17
1948	4.12	2.40	5.19	4.18	8.69	3.17	2.92	1.12	0.34	2.38	5.86	5.59	45.96
1949	6.45	3.68	2.45	3.70	4.23	2.97	0.10	1.76	4.72	2.96	3.00	3.59	39.61
1950	3.85	3.44	2.86	2.53	5.43	2.89	3.11	4.84	0.99	2.42	3.98	4.49	40.83
Av. 10 Yrs.	3.63	2.70	3.75	3.34	4.59	3.28	2.85	3.86	2.52	2.71	5.03	4.05	42.31

WEST HARTFORD, CONN. (West Hartford Reservoir No. 1)—Elevation 275 feet
Record: January, 1868, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	2.42	3.43	2.44	1.01	3.44	4.76	4.42	2.76	1.18	1.76	3.58	4.54	35.74
1942	3.37	4.37	6.62	0.73	4.51	4.36	5.00	4.63	3.67	3.20	6.37	6.28	53.11
1943	2.99	2.28	4.13	2.92	5.92	2.97	—	1.67	0.97	6.12	4.46	0.85	—
1944	1.69	2.03	4.96	5.22	1.25	3.54	2.16	3.38	7.70	2.42	6.55	3.45	44.35
1945	—	—	—	—	—	—	5.00	3.89	2.61	—	5.51	5.31	—
1946	2.44	2.55	1.38	2.58	6.20	3.18	3.99	5.26	2.80	1.49	1.42	1.96	35.25
1947	—	1.67	2.87	4.03	4.69	4.92	5.75	2.37	3.23	2.64	6.58	2.32	—
1948	3.59	1.85	3.53	4.01	6.17	8.09	2.89	3.30	0.30	1.91	6.23	4.99	46.86
1949	5.24	2.60	2.65	4.42	5.73	0.79	2.99	2.61	4.27	2.12	2.05	3.39	38.86
1950	4.05	4.66	3.30	2.86	3.68	5.81	3.85	4.71	1.00	2.17	6.47	4.20	46.76
Av. 80 Yrs.	3.50	3.23	3.79	3.42	3.64	3.51	3.99	4.26	3.64	3.54	3.71	3.39	43.62

WEST HARTLAND, CONN. (Hartford Water Bureau)—Elevation 1,180 feet
Record: January, 1936, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1936	6.35	2.63	8.48	3.66	3.09	3.76	1.20	4.69	3.16	4.21	1.70	5.45	48.38
1937	4.37	3.07	3.75	4.07	5.07	6.18	3.84	3.89	3.81	5.95	5.64	2.03	51.67
1938	5.70	1.83	2.20	3.55	3.75	7.41	7.86	3.37	12.90	1.93	3.66	2.93	57.09
1939	2.70	3.25	4.24	3.70	0.98	3.02	2.23	4.30	1.86	4.65	1.80	2.60	35.33
1940	2.45	3.15	4.70	5.81	5.61	5.11	2.77	2.70	3.03	2.37	6.10	2.60	46.40
1941	2.15	2.50	1.92	1.17	3.16	5.30	7.53	2.71	2.45	2.53	3.47	3.60	38.49
1942	2.35	2.25	6.69	0.82	6.10	4.55	6.24	3.05	4.74	3.04	5.92	5.35	51.10
1943	3.22	1.63	3.13	3.60	5.67	3.76	5.37	0.71	2.80	5.99	5.56	0.62	42.06
1944	1.36	2.08	4.40	3.86	1.75	6.70	3.92	2.81	7.65	2.22	6.41	4.13	47.29
1945	4.49	3.90	2.33	5.72	7.72	6.60	6.39	4.41	3.52	2.78	4.80	4.38	57.04

WEST HARTLAND, CONN. (Continued)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1946	2.85	3.01	1.80	2.22	7.23	3.15	5.10	2.65	4.29	2.00	1.25	2.87	38.42
1947	2.88	3.04	4.17	4.11	6.03	3.55	6.39	2.52	4.00	2.51	5.93	2.81	47.94
1948	3.54	1.91	3.94	3.00	5.78	6.02	3.50	1.72	1.26	2.28	5.09	8.60	46.64
1949	6.60	1.97	3.43	3.35	5.54	1.37	4.12	2.52	3.55	1.74	1.46	3.05	38.70
1950	4.29	4.85	—	2.78	4.01	4.63	3.00	4.91	1.99	2.05	7.89	5.37	—
Av. 14 Yrs.	3.64	2.59	3.94	3.47	4.82	4.75	4.75	3.00	4.22	3.16	4.20	3.64	46.18

WHIGVILLE RESERVOIR, CONN. (Burlington)—Elevation 570 feet
Record: January, 1921, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	3.05	3.88	6.80	0.69	4.65	5.84	4.80	4.09	2.89	2.68	6.32	5.98	51.67
1943	3.32	1.78	3.85	2.91	6.50	3.99	2.89	1.45	1.86	5.88	4.71	0.87	40.01
1944	1.97	1.99	4.72	3.93	1.97	3.78	3.04	0.98	8.41	2.13	6.15	3.64	42.71
1945	3.72	4.15	2.66	5.58	6.99	3.88	6.53	5.44	4.13	2.42	5.55	5.27	56.32
1946	2.57	2.49	1.67	2.43	6.42	3.25	4.64	3.44	4.55	2.02	1.46	2.80	37.74
1947	2.53	2.54	3.07	4.03	4.62	4.64	6.54	2.97	3.05	2.47	7.30	2.36	46.12
1948	3.73	2.10	3.68	4.03	6.24	6.34	2.64	2.22	0.32	2.49	6.50	6.99	47.28
1949	7.31	2.71	2.76	4.16	6.14	0.64	4.23	1.82	3.58	2.20	1.72	3.93	41.20
1950	4.08	3.95	3.05	3.13	3.40	6.24	4.54	4.50	1.70	2.07	5.49	5.60	47.75
Av. 30 Yrs.	3.65	2.83	3.39	3.83	4.13	3.98	4.21	3.70	3.85	3.06	4.02	3.45	44.10

WIGWAM RESERVOIR, CONN. (Thomaston)—Elevation 576 feet
Record: January, 1924, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1942	2.71	3.67	7.17	0.97	6.23	4.13	4.24	4.03	3.71	3.60	6.24	7.20	53.90
1943	3.69	1.70	3.81	3.46	8.22	3.71	3.59	1.96	2.24	4.96	4.61	1.00	42.95
1944	1.87	2.05	5.23	4.41	2.12	3.44	4.85	0.84	7.50	2.11	6.35	3.70	44.47
1945	—	—	—	—	—	—	7.25	5.42	2.90	—	5.43	5.92	—
1946	2.56	3.11	1.97	2.39	6.26	3.03	5.68	5.43	6.34	1.60	1.61	2.67	42.65
1947	2.80	3.11	3.30	4.08	4.47	4.60	5.48	1.27	3.10	1.52	6.99	3.62	44.34
1948	3.78	2.36	4.31	3.79	7.31	5.58	2.63	2.88	0.36	2.40	5.25	9.08	49.73
1949	6.06	—	3.25	3.25	5.36	0.78	5.60	4.33	3.90	2.38	1.91	4.77	—
1950	—	—	2.92	2.71	—	7.26	4.82	3.87	1.50	1.46	6.49	5.14	—
Av. 24 Yrs.	3.66	3.21	3.77	3.78	4.22	4.04	4.16	4.84	4.06	2.88	4.20	3.59	46.41

WOLCOTT, CONN. (Wolcott Reservoir)—Elevation 768 feet
Record: January, 1930, to December, 1950

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1941	2.94	4.93	2.25	1.41	2.67	4.82	4.03	3.59	0.92	3.16	3.35	5.24	39.31
1942	3.56	5.17	7.87	0.98	4.64	3.06	3.96	7.14	3.87	3.30	6.79	7.67	58.01
1943	3.61	2.51	4.45	3.31	6.38	3.43	2.41	1.62	1.17	6.49	5.19	1.07	41.64
1944	2.51	2.28	5.47	4.52	2.14	2.59	3.98	1.35	9.96	2.22	6.65	4.14	47.81
1945	—	—	—	—	—	—	6.76	4.51	3.96	—	6.01	5.96	—
1946	2.49	2.43	2.03	2.78	8.11	4.00	4.61	6.82	4.02	2.01	2.23	2.91	44.44
1947	2.91	3.43	3.70	4.90	5.61	5.54	6.88	2.70	3.45	2.37	9.34	3.36	54.19
1948	4.57	2.34	4.40	5.21	7.50	5.91	3.42	2.56	0.47	2.76	7.27	8.81	55.22
1949	7.92	2.98	2.97	5.71	5.98	0.61	4.94	7.21	5.09	2.57	2.17	4.56	52.71
1950	4.31	4.06	4.00	3.55	3.86	4.29	4.41	3.82	1.53	2.46	7.98	6.90	51.17
Av. 20 Yrs.	4.27	3.20	4.47	4.06	4.62	4.40	4.20	4.11	4.32	3.16	4.68	4.20	49.69

PROCEEDINGS

FEBRUARY 1957 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, FEBRUARY 21, 1957

President Edward L. Tracy in the Chair.

Secretary Knox announced the election of the following to membership in the Association:

Edward F. Capaldi, Sewer and Water Works Construction, Pawtucket, R. I.; Morris M. Cohn, Editorial Director, "Water Works Engineering", New York, N. Y.; Robert E. Galipeau, Foreman, Water Department, North Adams, Mass.; Robert T. Koopman, Project Engineer, Metcalf & Eddy, Boston, Mass.; William W. Wedge, Service Supervisor, Bridgeport Hydraulic Co., Bridgeport, Conn.; Walter M. White, Superintendent of Distribution, Water Department, North Attleborough, Mass.; George R. Winters, Director of Public Works, Wakefield, Mass.; Donald H. Bodge, Assistant Superintendent, Portland Water District, Portland, Me.

Papers in connection with the water-system improvements at Taunton, Mass., were read as follows:

"Water-System Improvements, Taunton, Mass.," by Thomas B. Williams, Jr., Superintendent, Water Department, Taunton, Mass.; "How the Pumping Station Was Modernized," by Frank J. Turnbull, Senior Mechanical Engineer, Fay, Spofford & Thorndike, Inc., Boston, Mass.; "The Distribution Reservoir," by Fozi M. Cahaly, Director, Fay, Spofford & Thorndike, Inc., Boston, Mass.

MARCH 1957 MEETING

HOTEL STATLER, BOSTON, MASS.

THURSDAY, MARCH 21, 1957

President Edward L. Tracy in the Chair.

PRESIDENT TRACY. Two members of the New England Water Works Association have died. Horace L. Clark died March 3, 1957. He joined the New England Water Works Association in 1929 and was President during the years 1943-44. Also Carleton E. Davis died in January of this year in Philadelphia. He became a member in 1902 and was President in 1918. May I ask that you all stand for just a moment. (*The members stand.*)

Secretary Knox announced the election by the Executive Committee of the following new members:

Henry G. Quinn, Water Commissioner, East Chelmsford, Mass.; William H. Spaulding, Jr., Superintendent, Water Department, Lincoln, R. I.; Lawrence K. Engdahl, Water Engineer, Milton, Mass.

On motion of Richard H. Ellis, duly seconded, it was VOTED that the last five preceding Presidents of this association be members of the Nominating Committee, with the provision that Mr. Almquist be Chairman.

A talk on "Water and Its Importance in a Resource Development Program" was given by Francis W. Sargent, Commissioner, Massachusetts Department of Natural Resources, Boston, Mass.

A paper on "A Water Resource Program for Massachusetts" was read by Clarence I. Sterling, Jr., Engineering Consultant, Massachusetts Water Resources Commission, Boston, Mass.

MANUAL FOR THE COMPUTATION OF STRENGTH AND THICKNESS OF CAST IRON PIPE

On February 21, 1957, the Executive Committee of the New England Water Works Association voted approval of a document, designated "ASA A21.1—1956 (AWWA C101—56)" and entitled "Proposed Revision—American Recommended Practice—Manual for the Computation of Strength and Thickness of Cast Iron Pipe." This *Manual* contains a total of 171 pages, of which 119 pages are applicable to water pipe and the rest to gas pipe only.

Copies of the *Manual* are available for reference at the office of the New England Water Works Association, 73 Tremont St., Boston 8, Mass.

AWWA C600-54T
(*Formerly* 7D.1-T)

American Water Works Association

Tentative

Standard Specifications

for

INSTALLATION OF CAST-IRON WATER MAINS

These "Tentative Standard Specifications for Installation of Cast-Iron Water Mains" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and must be reviewed by the engineer responsible for the construction and modified as necessary to meet specific conditions pertaining to each individual installation.

Approved as Tentative by the Board of Directors of the A.W.W.A., June 3, 1949
Approval confirmed by the Executive Committee of the Board, November 14, 1949
Revised May 27, 1954

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Avenue, New York 16, N.Y.

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as part of the December 1949 and January 1955 Journal AWWA.

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Introduction

General

Standard specifications governing the construction of new water mains and the extension of existing mains must of necessity differ from specifications prepared for any particular project. Although both should include subject matter pertaining to the required work, materials and methods of construction, the latter can be made complete for any particular project by including therein a detailed description of the specific work, materials and methods applicable to that project. However, standard specifications, to be complete and serve their purpose, should include a detailed description of the several acceptable materials and methods of construction recognized as standard. Consequently, although the specifications for a particular project can be used without further supplementation, standard specifications must be accompanied by an appendix or addendum.

Standard Specifications and Addendum

The AWWA Specifications for Installation of Cast-Iron Water Mains can be made applicable to all water main construction projects by being supplemented with an adequate addendum for each project. The specifications presented herein include the various materials and methods of construction recognized as standard. The addendum, which must be prepared by the engineer, designates which of these various materials and methods of construction are to apply to a particular project. The addendum can also be expanded to cover work and materials not included in the specifications themselves.

Outline of Addendum

The "Outline of Addendum" included herein is intended to guide and aid the engineer in the preparation of the addendum to accompany the AWWA Specifications for the Installation of Cast-Iron Water Mains.

Limits of AWWA Specifications

These specifications cover several procedures for laying and testing a system of water mains and for the furnishing of sheeting, blocking and joint materials incidental thereto. They do not cover the furnishing and delivery of pipes, castings, fittings, valves and hydrants by manufacturers, or the laying and jointing of any pipe other than cast iron.

These specifications do not include the detailed procedure for the disinfection of water mains following their construction. However, reference is made to a separate document prepared and approved by the AWWA, entitled "A Procedure for Disinfecting Water Mains—AWWA C601."

Use of AWWA Specifications

It is contemplated that the A.W.W.A. Specifications for Installation of Cast-Iron Water Mains may be of service in their published form as a part of the specifications to be incorporated in the contract documents. If it is decided to so use them, a statement having the following import should be made under the title "Specifications":

The water mains shall be laid and the work incidental thereto performed in accordance with the Specifications for Installation of Cast-Iron Water Mains adopted by the American Water Works Association on June 3, 1949, and the Addendum attached hereto.

General Requirements

Since the contract documents for the construction of any project include among them the "General Requirements," it is recommended that the definitions, notices and permits, regulations, schedule of minimum wages, means of measurement and payment for work on unit basis and as extra work, and similar items not covered by these specifications be included therein.

Tentative Standard Specifications for

Installation of Cast-Iron Water Mains

Section 1—Scope

Sec. 1.1—General

These specifications and the addenda attached hereto form a part of the contract documents.

Sec. 1.2—Work Included

The contractor shall, unless specified otherwise, furnish all material, equipment, tools and labor necessary to do the work required under this contract and unload, haul and distribute all pipe, castings, fittings, valves, hydrants and accessories. The contractor shall also remove the pavement as stipulated; excavate the trenches and pits to the required dimensions; excavate the bell holes; construct and maintain all bridges for traffic control; sheet, brace and support the adjoining ground or structures where necessary; handle all drainage or ground water; provide barricades, guards and warning lights; lay and test the pipe, castings, fittings, valves, hydrants and accessories; backfill and consolidate the trenches and pits; restore the roadway surface unless otherwise stipulated; remove surplus excavated material; clean the site of the work; and maintain the street or other surface over the trenches as specified.

The contractor shall also furnish all equipment, tools, labor and materials required to rearrange branch connections to main sewers, or to rearrange sewers, conduits, ducts, pipes or other structures in accordance with the contract drawings and stipulations included herein.

Sec. 1.3—General Description of Work to Be Done

See Addendum Sec. 1.3.

Sec. 1.4—Schedule of Progress and Completion

See Addendum Sec. 1.4.

Sec. 1.5—List of Contract Drawings

See Addendum Sec. 1.5.

Sec. 1.6—Special Work to Be Performed

See Addendum Sec. 1.6.

Sec. 1.7—Materials to Be Furnished by Owner

See Addendum Sec. 1.7.

Sec. 1.8—Materials to Be Furnished by Contractor

See Addendum Sec. 1.8.

Sec. 1.9—Water Used

See Addendum Sec. 1.9.

Section 2—Inspection

Sec. 2.1—Shop Inspection

All materials furnished by the contractor are subject, at the discretion of the owner, to inspection and approval at the plant of the manufacturer. *See* Addendum Sec. 2.1.

Sec. 2.2—Field Inspection

All pipe and accessories shall be laid, jointed and tested under pressure for defects and leakage in the manner specified and in the presence of and as approved by the engineer.

Sec. 2.3—Disposition of Defective Material

All material found during the progress of the work to have cracks, flaws or other defects will be rejected by the engineer. All defective materials furnished by the contractor shall be promptly removed by him from the site. Any material furnished by the owner and found defective shall be set aside and removed from the site of the work by the owner.

Section 3—Responsibility for Material

Sec. 3.1—Responsibility for Material Furnished by Contractor

The contractor shall be responsible for all material furnished by him and shall replace at his own expense all such material found defective in manufacture or damaged in handling after delivery by the manufacturer. This shall include the furnishing of all material and labor required for the replacement of installed material discovered defective prior to the final acceptance of the work.

Sec. 3.2—Responsibility for Material Furnished by Owner

The contractor's responsibility for material furnished by the owner shall begin at the point of delivery thereof to said contractor. Materials already on the site shall become the contractor's responsibility on the day of the award of the contract. The contractor shall examine all material furnished by the owner at the time and place of delivery to him and shall reject all defective material. Any material furnished by the owner and installed by the contractor without discovery of such defects will, if found defective prior to final acceptance of the work, be replaced with sound material by the owner. The contractor, however, shall, at his own expense, furnish all supplies, labor and facilities necessary to remove said defective material and install the sound material in a manner satisfactory to the engineer.

Sec. 3.3—Responsibility for Safe Storage

The contractor shall be responsible for the safe storage of material furnished by or to him, and accepted by him, and intended for the work, until it has been incorporated in the completed project. The interior of all pipe, fittings and other accessories shall be kept free from dirt and foreign matter at all times. Valves and hydrants shall be drained and stored in a manner that will protect them from damage by freezing.

Sec. 3.4—Replacement of Damaged Material

Any material furnished by the owner that becomes damaged after acceptance by the contractor shall be replaced by the contractor at his own expense.

Section 4—Handling of Material

Sec. 4.1—Hauling

All materials furnished by the contractor shall be delivered and distributed at the site by the contractor. Materials furnished by the owner shall be picked up by the contractor at points designated in Addendum Sec. 4.1 and hauled to and distributed at the site.

Cast-iron pipe, fittings, valves, hydrants and accessories shall be loaded and unloaded by lifting with hoists or skidding so as to avoid shock or damage. Under no circumstances shall such materials be dropped. Pipe handled on skidways shall not be skidded or rolled against pipe already on the ground.

Sec. 4.2—At Site of Work

In distributing the material at the site of the work, each piece shall be unloaded opposite or near the place where it is to be laid in the trench.

Sec. 4.3—Care of Pipe Coating and Lining

Pipe shall be so handled that the coating and lining will not be damaged. If, however, any part of the coating or lining is damaged, the repair shall be made by the contractor at his expense in a manner satisfactory to the engineer.

Section 5—Alignment and Grade

Sec. 5.1—General

The water main shall be laid and maintained to the required lines and grades with fittings, valves and hydrants at the required locations; spigots centered in bells; and all valves and hydrant stems plumb.

Sec. 5.2—Deviations Occasioned by Other Structures

Wherever obstructions not shown on the plans are encountered during the progress of the work and interfere to such an extent that an alteration in the plan is required, the engineer shall have the authority to change the plans and order a deviation from the line and grade or arrange with the owners of the structures for the removal, relocation or reconstruction of the obstructions. If the change in plans results in a change in the amount of work by the contractor, such altered work shall be done on the basis of payment to the contractor for extra work or credit to the owner for less work. (*See* Note 5.2.)

Sec. 5.3—Caution in Excavation

The contractor shall proceed with caution in the excavation and preparation of the trench so that the exact location of underground structures, both known and unknown, may be determined, and he shall be held responsible for the repair of such structures when broken or otherwise damaged because of carelessness on his part.

Sec. 5.4—Subsurface Explorations

Whenever, in the opinion of the engineer, it is necessary to explore and excavate to determine the location of existing underground structures, the contractor shall make explorations and excavations for such purposes. If the contractor is required to perform additional work in making the explorations and excavations, extra compensation will be allowed for such additional work.

Sec. 5.5—Depth of Pipe

All pipe shall be laid to the depth shown on the contract drawings or as

required in Addendum Sec. 5.5. Any variation therefrom shall be made only at the order of the engineer. (*See* Note 5.5.)

Section 6—Excavation and Preparation of Trench

Sec. 6.1—Description

The trench shall be dug so that the pipe can be laid to the alignment and depth required, and it shall be excavated only so far in advance of pipelaying as specified in Addendum Sec. 6.1 or permitted by the engineer. The trench shall be so braced (Sec. 6.13 (p. 6)) and drained that the workmen may work therein safely and efficiently. It is essential that the discharge of the trench dewatering pumps be conducted to natural drainage channels, drains or sewers.

Sec. 6.2—Width of Trench

The width of the trench shall be ample to permit the pipe to be laid and jointed properly, and the backfill to be placed and compacted as specified. Trenches shall be of such extra width, when required, as will permit the convenient placing of timber supports, sheeting and bracing, and handling of specials. *See* Addendum Sec. 6.2 *and* Note 6.2.

Sec. 6.3—Bell Holes

Bell holes shall be provided at each joint to permit the jointing to be made properly.

Sec. 6.4—Pipe Clearance in Rocks

Ledge rock, boulders and large stones shall be removed to provide a clearance of at least 6 in. below and on each side of all pipe, valves and fittings for pipes 24 in. in diameter or less, and 9 in. for pipes larger than 24 in. in diameter.

The specified minimum clearances are the minimum clear distances which will be permitted between any part of the pipe and appurtenances being laid and any part, projection or point of such rock, boulder or stone.

Sec. 6.5—Excavation to Grade

The trench shall be excavated to the depth required so as to provide a uniform and continuous bearing and support for the pipe on solid and undisturbed ground at every point between bell holes, except that it will be permissible to disturb and otherwise damage the finished surface over a maximum length of 18 in. near the middle of each length of pipe by the withdrawal of pipe slings or other lifting tackle. Any part of the bottom of the trench excavated below the specified grade shall be corrected with approved material, thoroughly compacted as directed by the engineer. The finished subgrade shall be prepared accurately by means of hand tools.

The subgrade beneath the centerline of the pipe shall be finished to within 0.03 ft. of a straight line between pipe joints or batter boards, and all tolerances shall be above the specified grade.

If, in the opinion of the engineer, soil conditions are encountered at subgrade which require all or part of the work to be done in accordance with Sec. 6.6, the engineer shall have the authority to order the work to be so done, and the contractor will be allowed extra compensation for the additional work. *See* Sec. 6.10 (p. 6) *and* Addendum Sec. 6.5; *see also* Note 6.5 (a) *and* Note 6.5 (b).

Sec. 6.6—Excavation Below Grade

The trench shall be excavated to at least 3 in. and not more than 6 in below the specified grade. Before the

pipe is laid, the subgrade shall be made by backfilling with an approved material in 3-in. uncompacted layers. The layers shall be thoroughly tamped as directed by the engineer so as to provide a uniform and continuous bearing and support for the pipe at every point between bell holes, except that it will be permissible to disturb and otherwise damage the finished surface over a maximum length of 18 in. near the middle of each length of pipe by the withdrawal of pipe slings or other lifting tackle. The finished subgrade shall be prepared accurately by means of hand tools.

The subgrade beneath the centerline of the pipe shall be finished to within 0.03 ft. of a straight line between pipe joints or batter boards, and all tolerances shall be above the specified grade. *See* Sec. 6.10 (p. 6) *and* Addendum Sec. 6.6; *see also* Note 6.5 (a) *and* Note 6.6.

Sec. 6.7—Excavation in Poor Soil and Refilling to Grade

Where the bottom of the trench at subgrade is found to be unstable or to include ashes, cinders, all types of refuse, vegetable or other organic material, or large pieces or fragments of inorganic material which in the judgment of the engineer should be removed, the contractor shall excavate and remove such unsuitable material to the width and depth ordered by the engineer. Before the pipe is laid, the subgrade shall be made by backfilling with an approved material in 3-in. uncompacted layers. The layers shall be thoroughly tamped as directed by the engineer so as to provide a uniform and continuous bearing and support for the pipe at every point between bell holes, except that it will be permissible to disturb and otherwise damage the finished surface over a maximum length of 18 in. near the middle of each length of pipe by the withdrawal of pipe slings or other lifting tackle. The finished subgrade shall be prepared accurately by means of hand tools.

The subgrade beneath the centerline of the pipe shall be finished to within 0.03 ft. of a straight line between pipe joints or batter boards, and all tolerances shall be above the specified grade.

The contractor will be allowed extra compensation for the additional work. *See* Sec. 6.10 *and* Note 6.5 (a).

Sec. 6.8—Special Foundation in Poor Soil

Where the bottom of the trench at subgrade is found to consist of material which is unstable to such a degree that, in the opinion of the engineer, it cannot be removed and replaced with an approved material thoroughly compacted in place to support the pipe properly, the contractor shall construct a foundation for the pipe, consisting of piling, timbers or other materials, in accordance with plans prepared by the engineer. Extra compensation will be allowed for the additional work.

Sec. 6.9—Subgrade in Rock Trenches

Where excavation is made in rock or boulders and the clearance specified in Sec. 6.4 is provided, the subgrade shall be made by backfilling with an approved material in 3-in. uncompacted layers. The layers shall be thoroughly tamped as directed by the engineer so as to provide a uniform and continuous bearing and support for the pipe at every point between bell holes, except that it will be permissible to disturb and otherwise damage the finished surface over a maximum length of 18 in. near the middle of each pipe length by the withdrawal of

pipe slings or other lifting tackle. The finished subgrade shall be prepared accurately with hand tools.

The subgrade beneath the centerline of the pipe shall be finished to within 0.03 ft. of a straight line between pipe joints or batter boards, and all tolerances shall be above the specified grade. *See* Sec. 6.10.

Sec. 6.10—Subgrade for Blocking

Where blocking is ordered in accordance with Sec. 8 (p. 9), the trench shall be excavated to at least 2 in. and not more than 4 in. below the specified grade and the blocking laid as specified.*

Where, in the opinion of the engineer, the bottom of the trench at subgrade is found to be unsuitable for blocking, the engineer shall have the authority to order additional excavation and backfilling with an approved material, which shall be placed in 3-in. uncompacted layers and thoroughly tamped to an elevation of 2 in. below the specified grade so as to support the blocking properly.

The contractor will be allowed extra compensation for the additional work. *See* Addendum Sec. 6.10 *and* Note 6.5 (a).

Sec. 6.11—Rock Excavation

The word "rock," wherever used as the name of an excavated material, shall mean boulders and pieces of concrete or masonry exceeding 250 lb. in weight, or solid ledge rock and masonry which, in the opinion of the engineer, requires for its removal drilling and blasting, wedging, sledging or barring, or breaking up with a power-operated hand tool. No soft or disintegrated rock which can be removed with a hand pick or power-operated excavator or shovel; no loose, shaken or previously blasted rock or broken stone in rock fillings or elsewhere; and no rock exterior to the minimum limits of measurement allowed, which may fall into the excavation, will be measured or allowed.

Sec. 6.12—Blasting

Blasting for excavation will be permitted only after securing the approval of the engineer and only when proper precautions are taken for the protection of persons or property. The hours of blasting will be fixed by the engineer. Any damage caused by blasting shall be repaired by the contractor at his expense. The contractor's methods of procedure in blasting shall conform to state laws and municipal ordinances.

Sec. 6.13—Braced and Sheeted Trenches

Open-cut trenches shall be sheeted and braced as required by any governing state laws and municipal ordinances, and as may be necessary to protect life, property or the work. When close sheeting is required, it shall be so driven as to prevent adjacent soil from entering the trench either below or through such sheeting. Where sheeting and bracing are used, the trench width shall be increased accordingly.

The engineer reserves the right to order the sheeting driven to the full depth of the trench or to such additional depths as may be required for the protection of the work. Where the soil in the lower limits of a trench has the necessary stability, the engineer, at his discretion, may permit the contractor to stop the driving of sheeting at some designated elevation above the trench bottom. The granting of permission by the engineer, however, shall not relieve the contractor in any de-

* Blocking is not recommended. See p. 9.

gree from his full responsibility under the contract.

Sheeting and bracing which have been ordered left in place must be removed for a distance of 3 ft. below the established street grade or the existing surface of the street, whichever is lower. Trench bracing, except that which must be left in place, may be removed when the backfilling has reached the respective levels of such bracing. Sheeting, except that which has been left in place, may be removed after the backfilling has been completed or has been brought up to such an elevation as to permit its safe removal. Sheeting and bracing may be removed before flushing the trench, but only in such manner as will insure the adequate protection of the completed water structures and adjacent underground or surface structures, and prevent the disturbance of adjacent ground.

The cost of furnishing, placing and removing the sheeting and bracing and the leaving in place of sheeting and bracing indicated on the plans shall be included in the price bid for the work. When sheeting and bracing have been ordered by the engineer, or when such sheeting and bracing have been ordered left in place by the engineer, the payment for same shall be as an extra. When sheeting and bracing have been ordered left in place, payment for same shall include the upper 3 ft. or "cut-off" section of the sheeting.

Sec. 6.14—Care of Surface Material for Reuse

All surface materials which, in the opinion of the engineer, are suitable for reuse in restoring the surface shall be kept separate from the general excavation material, as directed by the engineer.

Sec. 6.15—Piling Excavated Material

All excavated material shall be piled in a manner that will not endanger the work and that will avoid obstructing sidewalks and driveways. Hydrants under pressure, valve pit covers, valve boxes, curb stop boxes, fire and police call boxes, or other utility controls shall be left unobstructed and accessible until the work is completed. Gutters shall be kept clear or other satisfactory provisions made for street drainage, and natural watercourses shall not be obstructed.

Sec. 6.16—Trenching by Hand or Machine

Hand methods for excavation shall be employed in locations shown on the drawings. In other locations the contractor may use trench-digging machinery or employ hand methods.

Sec. 6.17—Barricades, Guards and Safety Provisions

To protect persons from injury and to avoid property damage, adequate barricades, construction signs, torches, red lanterns and guards as required shall be placed and maintained during the progress of the construction work and until it is safe for traffic to use the highway. All material piles, equipment and pipe which may serve as obstructions to traffic shall be enclosed by fences or barricades and shall be protected by proper lights when the visibility is poor. The rules and regulations of the local authorities respecting safety provisions shall be observed.

Sec. 6.18—Maintenance of Traffic and Closing of Streets

The contractor shall carry on the work in a manner which will cause the least interruption to traffic, and may

close to through travel not more than two consecutive blocks, including the cross street intersected. Where traffic must cross open trenches, the contractor shall provide suitable bridges at street intersections and driveways.

The contractor shall post, where directed by the engineer, suitable signs indicating that a street is closed and necessary detour signs for the proper maintenance of traffic.

Sec. 6.19—Structure Protection

Temporary support, adequate protection and maintenance of all underground and surface structures, drains, sewers and other obstructions encountered in the progress of the work shall be furnished by the contractor at his expense and under the direction of the engineer. The structures which may have been disturbed shall be restored upon completion of the work.

Sec. 6.20—Protection of Property and Surface Structures

Trees, shrubbery, fences, poles and all other property and surface structures shall be protected unless their removal is shown on the drawings or authorized by the engineer. When it is necessary to cut roots and tree branches, such cutting shall be done under the supervision and direction of the engineer. *See* Sec. 15.3 (p. 20).

Sec. 6.21—Interruption of Service

No valve or other control on the existing system shall be operated for any purpose by the contractor. The owner will operate all valves, hydrants, blow-offs and curb stops.

Section 7—Laying

Sec. 7.1—Handling of Water Main Material Into Trench

Proper implements, tools and facilities satisfactory to the engineer shall be provided and used by the contractor for the safe and convenient prosecution of the work. All pipe, fittings, valves and hydrants shall be carefully lowered into the trench piece by piece by means of a derrick, ropes or other suitable tools or equipment, in such a manner as to prevent damage to water main materials and protective coatings and linings. Under no circumstances shall water main materials be dropped or dumped into the trench.

Sec. 7.2—Hammer Test

The pipe and fittings shall be inspected for defects and, while suspended above grade, be rung with a light hammer to detect cracks.

Sec. 7.3—Cleaning Pipe and Fittings

All lumps, blisters and excess coal-tar coating shall be removed from the bell-and-spigot end of each pipe, and the outside of the spigot and the inside of the bell shall be wire-brushed and wiped clean and dry and free from oil and grease before the pipe is laid.

Sec. 7.4—Laying Pipe

Every precaution shall be taken to prevent foreign material from entering the pipe while it is being placed in the line. If the pipe-laying crew cannot put the pipe into the trench and in place without getting earth into it, the engineer may require that before lowering the pipe into the trench, a heavy, tightly woven canvas bag of suitable size shall be placed over each end and left there until the connection is to be made to the adjacent pipe. During laying operations, no debris,

tools, clothing or other materials shall be placed in the pipe.

After placing a length of pipe in the trench, the spigot end shall be centered in the bell and the pipe forced home and brought to correct line and grade. The pipe shall be secured in place with approved backfill material tamped under it except at the bells. Pipe and fittings which do not allow a sufficient and uniform space for joints shall be removed and replaced with pipe and fittings of proper dimensions to insure such uniform space. Precautions shall be taken to prevent dirt from entering the joint space.

At times when pipe laying is not in progress, the open ends of pipe shall be closed by a watertight plug or other means approved by the engineer. Joints of pipe in the trench which cannot be poured (*see* Sec. 7.5) shall be calked with packing to make them as watertight as possible. This provision shall apply during the noon hour as well as overnight. If water is in the trench, the seal shall remain in place until the trench is pumped completely dry.

Sec. 7.5—Number of Pipes Laid Before Jointing

Wherever the jointing material specified is cement, six or more lengths of pipe shall be in place ahead of each joint before such joint is finished.

Sec. 7.6—Cutting Pipe

The cutting of pipe for inserting valves, fittings or closure pieces shall be done in a neat and workmanlike manner without damage to the pipe or cement lining and so as to leave a smooth end at right angles to the axis of the pipe.

When machine cutting is not available for cutting pipe 20 in. in diameter or larger, the electric-arc cutting method will be permitted using a carbon or steel rod. Only qualified and experienced workmen shall be used on this work.

The flame cutting of pipe by means of an oxyacetylene torch shall not be allowed.

Sec. 7.7—Bell Ends to Face Direction of Laying

Pipe shall be laid with bell ends facing in the direction of laying, unless directed otherwise by the engineer.

Sec. 7.8—Permissible Deflection at Joints

Wherever it is necessary to deflect pipe from a straight line, either in the vertical or horizontal plane, to avoid obstructions or plumb stems, or where long-radius curves are permitted, the amount of deflection allowed shall not exceed that required for satisfactory calking of the joint, and shall be approved by the engineer. *See* Addendum Sec. 7.8 *and* Note 7.8.

Sec. 7.9—Railroad and Street Railway Crossings

See Addendum Sec. 7.9.

Sec. 7.10—Unsuitable Conditions for Laying Pipe

No pipe shall be laid in water or when, in the opinion of the engineer, trench conditions are unsuitable.

Section 8—Blocking

Blocking of cast-iron pipe is not recommended and is not ordinarily used in modern practice. When special conditions indicate the desirability of the use of blocking, the following statements are indicative of an accept-

able method. These comments also govern the application of Sec. 6.10 and Note 8.3.

Sec. 8.1—Support Required

See Sec. 6.10 *and* Addendum Sec. 8.1.

Sec. 8.2—General

Pipe shall be laid on wood blocking and held in position by wood wedges. Blocking and wedges shall be cut from sound lumber.

Sec. 8.3—Dimensions

The number and size of blocks shall be as specified in Addendum Sec. 8.3. (*See* Note 8.3.)

Sec. 8.4—Spacing of Blocks

Blocks shall be placed 3 ft. from the joint where only one block is used per length of pipe, 4 ft. from the joint where two blocks are used for pipes 16 ft. long, and 5 ft. from the joint where two blocks are used for pipes 18 ft. and 20 ft. long.

Sec. 8.5—Placing of Wood Blocking

Blocks shall be bedded firmly with uniform bearing and with the long side tangent and crosswise to the outside of the pipe barrel. Blocks shall not be embedded in any manhole or buttress or act as a support for such structures.

Section 9a—Jointing Bell-and-Spigot Pipe

Sec. 9a.1—Yarning or Packing Material

Yarning or packing material shall consist of one of the following: [1] molded or tubular rubber rings, [2] asbestos rope or [3] treated paper rope. All of the above materials shall be handled with care in order to prevent contamination and shall be dry when put into place in the joint. The material used shall be free of oil, tar or greasy substances. In cement joints, the yarning material may be omitted if so specified. *See* Addendum Sec. 9a.1.

Sec. 9a.2—Placing of Yarning Material

The yarning material shall be placed around the spigot of the pipe and shall be of proper dimensions to center the spigot in the bell. When the spigot is shoved home, the yarning material shall be driven tightly against the inside base or hub of the bell with suitable yarning tools.

When a single strand of yarning material is used, it shall have an overlap at the top of not more than 2 in. When more than a single strand is required for a joint, each strand shall be cut to sufficient length so that the ends will meet without causing overlap. The ends of the strands shall meet on opposite sides of the pipe and not on the top or at the bottom. Successive strands of yarning material shall be driven home separately.

Sec. 9a.3—Depth of Jointing Material

For lead joints a space not less than 2¼ in. in depth shall be left in the bell in pipe having a nominal diameter of 20 in. or less; 2½ in. in 24-, 30- and 36-in. pipe; and 3 in. in pipe larger than 36 in.

When cement is specified, a space not less than 3 in. in depth shall be left in the bell unless it is specified that the yarning material or packing shall be omitted. *See* Addendum Sec. 9a.1.

Sec. 9a.4—Lead Joints

See Addendum Sec. 9a.4.

Sec. 9a.5—Lead

Lead for calking purposes shall contain not less than 99.73 per cent pure lead. Impurities shall not exceed the following limits:

	per cent
Arsenic, antimony & tin together	0.015
Copper	0.08
Zinc	0.002
Iron	0.002
Bismuth	0.25
Silver	0.02

The producer's name or the mark of Lead Industries shall be clearly cast or stamped upon each piece of lead.

Sec. 9a.6—Heating and Pouring of Lead

Lead shall be heated in a melting pot kept in easy reach of the joint to be poured—so that the molten metal will not be chilled in being carried from the melting pot to the joint—and shall be brought to a proper temperature so that when stirred it will show a rapid change of color. Before pouring, all scum shall be removed. Each joint shall be made with one continuous pour filling the entire joint space with solid lead. Spongy or imperfectly filled joints shall be burned out and repoured.

Sec. 9a.7—Position of Joint Runner

The joint runner shall fit snugly against the face of the bell and the outside of the pipe and shall be dammed with clay to form a pouring lip to provide for filling the joint flush with the face and to the top of the bell.

Sec. 9a.8—Calking Lead Joints

After the lead has cooled to the temperature of the pipe, lead joints shall be calked with pneumatic or hand tools operated by competent workmen, until such joints are thoroughly compacted and watertight. The finished joint shall show a hard and even hammered surface overall. Care should be taken not to overstrain the bells during calking.

Sec. 9a.9—Cement Joints

See Addendum Sec. 9a.9 *and* Note 9a.9.

Sec. 9a.10—Cement

All cement shall be of an approved brand acceptable to the engineer and shall comply with the current specifications of the American Society for Testing Materials.

Sec. 9a.11—Proportions of Cement and Water

One quart of cement shall be thoroughly mixed with about ¼ pint of water. The mixture shall be such that when it is tightly compressed by hand into a ball and the ball is broken into two pieces, the break shall be clean. If the hand is water-stained, the mixture is too wet. If there is evidence of crumbling in the break, the mixture is too dry. The cement mixture shall ring with a metallic sound while being calked.

Sec. 9a.12—Cause for Rejection

No cement shall be used after having been wet more than one hour or after its initial set.

Sec. 9a.13—Calking Cement Joints

Starting at the bottom, the joint space shall be filled with the cement mixture and the mixture calked. The remaining joint space shall then be

refilled and calked until the joint is practically flush with the face of the bell. The mixture shall be thoroughly compacted to make a watertight joint without overstraining the bell.

Sec. 9a.14—Trench Water and Initial Set

No water shall be allowed to touch the joint until the initial set has taken place.

Sec. 9a.15—Joints Kept Moist Until Set

Cement joints shall be covered immediately with damp burlap, or other material approved by the engineer, for the proper time to insure complete hydration. In cold weather, care shall be taken to prevent freezing of the cement mixture before and after the joint is made.

Sec. 9a.16—Time Interval Before Filling Pipe

Pipe laid with cement joints shall not be filled with water until a lapse of twelve hours after the last joint in any valved section has been made, and pressure shall not be permitted in the pipe until all joints have aged as provided in Sec. 13.10.

NOTE: *Certain materials are omitted from the preceding list, pending the completion of investigations now in progress.* See *Note 9a.*

Section 9b—Jointing Mechanical-Joint Pipe

Sec. 9b.1—Prior Requirements Apply

The general requirements in Sections 1–8 inclusive shall apply except that, where the terms "bell" and/or "spigot" are there used, they shall be considered to refer to the bell and spigot ends of the lengths of mechanical-joint pipe.

Sec. 9b.2—Variations in Dimensions

The outside diameter of the spigot end of bell-and-spigot pipe varies with the type, size, and class of pipe. There is only one joint size for each diameter of mechanical-joint pipe. Thus, difficulty may be met when attempts are made to connect existing bell-and-spigot lines to mechanical-joint pipe. When such a connection must be made, an adapter having a fitting bell and a mechanical-joint socket is manufactured and may be used.*

Sec. 9b.3—Cleaning and Assembling Joint

The last 8 in. outside of the spigot and inside of the bell of mechanical-joint pipe shall be thoroughly cleaned to remove oil, grit, tar (other than standard coating), and other foreign matter from the joint, and then painted with a soap solution made by dissolving one-half cup of granulated soap in 1 gal of water. The cast-iron gland shall then be slipped on the spigot end of the pipe with the lip extension of the gland toward the socket or bell end. The rubber gasket shall be painted with the soap solution and placed on the spigot end with the thick edge toward the gland.

* If the existing line ends in a spigot, either a standard sleeve or a special fitting consisting of a bell and mechanical-joint socket may be used, provided that the fitting between the spigot end of the existing line and the bell to be connected to it is consistent with the normal fit of bell-and-spigot pipe.

Sec. 9b.4—Bolting of Joint

The entire section of the pipe shall be pushed forward to seat the spigot end in the bell. The gasket shall then be pressed into place within the bell, being careful to have the gasket evenly located around the entire joint. The cast-iron gland shall be moved along the pipe into position for bolting, all of the bolts inserted, and the nuts screwed up tightly with the fingers. All nuts shall be tightened with a suitable (preferably torque-limiting) wrench. The torque for various sizes of bolts shall be as follows:

Size *in.*	Range of Torque *ft-lb*
⅝	40– 60
¾	60– 90
1	70–100
1¼	90–120

Nuts spaced 180 deg apart shall be tightened alternately in order to produce an equal pressure on all parts of the gland.

Reference should be made to the "Notes on Method of Installation" included in American Standard Specifications for a Mechanical Joint for Cast Iron Pressure Pipe and Fittings—A21.11 (AWWA C111). See also Note 9b.4.

Sec. 9b.5—Permissible Deflection in Mechanical-Joint Pipe

Whenever it is desirable to deflect mechanical-joint pipe in order to form a long-radius curve, the amount of deflection shall not exceed the maximum limits shown in the table below.

*Maximum Permissible Deflection in Laying Mechanical-Joint Pipe**

Size of Pipe *in.*	Max. Permissible Deflection per Length—*in.*				Approx. Radius of Curve Produced by Succession of Joints—*ft*			
	12-ft Length	16-ft Length	18-ft Length	20-ft Length	12-ft Length	16-ft Length	18-ft Length	20-ft Length
3	21	28	31		85	110	125	
4	21	28	31		85	110	125	
6	18	24	27		100	130	145	
8	13	18	20		130	170	195	
10	13	18	20		130	170	195	
12	13	18	20	22	130	170	195	220
14	9	12	13½	15	190	250	285	320
16	9	12	13½	15	190	250	285	320
18	7½	10	11	12	230	300	340	380
20	7½	10	11	12	230	300	340	380
24	6	8	9	10	300	400	450	500
30	6	8	9	10	300	400	450	500
36	5	7	8		330	440	500	
42	5	6	7½		340	450	510	
48	5	6	7½		340	450	510	

* Pipe conforming to A21.2 (pit cast) is commonly made in 12-ft lengths; to A21.6 (centrifugally cast in metal molds), in 12- and 18-ft lengths; and to A21.8 (centrifugally cast in sand-lined molds), in 16-, 16½-, and 20-ft lengths.

Section 10—Setting Valves and Fittings

Sec. 10.1—General

Valves, fittings, plugs and caps shall be set and jointed to pipe in the manner heretofore specified for cleaning, laying and jointing pipe.

Sec. 10.2—Location of Valves

Valves in water mains shall, where possible, be located on the street property lines extended unless shown otherwise on the plans.

Sec. 10.3—Valve Boxes and Valve Pits

A valve box or a masonry pit shall be provided for every valve.

A valve box shall be provided for every valve which has no gearing or operating mechanism or in which the gearing or operating mechanism is fully protected with a cast-iron grease case. The valve box shall not transmit shock or stress to the valve and shall be centered and plumb over the wrench nut of the valve, with the box cover flush with the surface of the finished pavement or such other level as may be directed.

A masonry valve pit shall be provided for every valve which has exposed gearing or operating mechanisms. The valve nut shall be readily accessible for operation through the opening in the manhole, which shall be set flush with the surface of the finished pavement or such other level as may be specified. Pits shall be so constructed as to permit minor valve repairs and afford protection to the valve and pipe from impact where they pass through the pit walls.

Sec. 10.4—Drainage of Mains

Mains shall be drained through drainage branches or blowoffs to dry wells from which the water can be pumped. Drainage branches, blowoffs, air vents and appurtenances shall be provided with gate valves and shall be located and installed as shown on the plans.

Drainage branches or blowoffs shall not be connected to any sewer, submerged in any stream or be installed in any other manner that will permit back siphonage into the distribution system.

Sec. 10.5—Dead Ends

All dead ends on new mains shall be closed with cast-iron plugs or caps, with or without a blowoff cock, as shown on the drawings.

Section 11—Setting Hydrants

Sec. 11.1—Location

Hydrants shall be located as shown or as directed and in a manner to provide complete accessibility, and also in such a manner that the possibility of damage from vehicles or injury to pedestrians will be minimized.

When placed behind the curb, the hydrant barrel shall be set so that no portion of the pumper or hose nozzle cap will be less than 6 in. nor more than 12 in. from the gutter face of the curb.

When set in the lawn space between the curb and the sidewalk, or between the sidewalk and the property line, no portion of the hydrant or nozzle cap shall be within 6 in. of the sidewalk.

Sec. 11.2—Position

All hydrants shall stand plumb and shall have their nozzles parallel with or at right angles to the curb, with the pumper nozzle facing the curb, except that hydrants having two hose nozzles 90 deg. apart shall be set with each nozzle facing the curb at an angle of 45 deg. Hydrants shall be set to the established grade, with nozzles at least 12 in. above the ground, as shown or as directed by the engineer.

Sec. 11.3—Connection to Main

Each hydrant shall be connected to the main with a 6-in. cast-iron branch controlled by an independent 6-in. gate valve, except as otherwise directed.

Sec. 11.4—Hydrant Drainage in Pervious Soil

Wherever a hydrant is set in soil that is pervious, drainage shall be provided at the base of the hydrant by placing coarse gravel or crushed stone mixed with coarse sand, from the bottom of the trench to at least 6 in. above the waste opening in the hydrant and to a distance of 1 ft. around the elbow. No drainage system shall be connected to a sewer. *See* Note 11.4 *and* Addendum Sec. 11.4.

Sec. 11.5—Hydrant Drainage in Impervious Soil

Wherever a hydrant is set in clay or other impervious soil, a drainage pit 2 ft. in diameter and 3 ft. deep shall be excavated below each hydrant and filled compactly with coarse gravel or crushed stone mixed with coarse sand, under and around the elbow of the hydrant and to a level of 6 in. above the waste opening. No drainage pit shall be connected to a sewer. *See* Addendum Sec. 11.5.

Section 12—Anchorage

Sec. 12.1—Anchorage for Hydrants

The bowl of each hydrant shall be well braced against unexcavated earth at the end of the trench with stone slabs or concrete backing, or it shall be tied to the pipe with suitable metal tie rods or clamps, as shown or directed by the engineer. *See* Addendum Sec. 12.1.

Sec. 12.2—Anchorage for Plugs, Caps, Tees and Bends

All plugs, caps, tees and bends deflecting 22½ deg. or more on mains 8 in. in diameter or larger shall be provided with a reaction backing, or movement shall be prevented by attaching suitable metal rods or clamps as shown or specified.* *See* Note 12.2.

Sec. 12.3—Reaction Backing

Reaction backing shall be concrete of a mix not leaner than 1 cement: 2½ sand: 5 stone, and having a compressive strength of not less than 2,000 psi. at 28 days. Backing shall be

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* NOTE: Consideration is being given by the committee to the rewording of Sec. 12.2 as follows: "All plugs, caps, tees and bends deflecting 22½ deg. or more on mains 8 in. in diameter or larger shall, unless otherwise indicated, be anchored to prevent movement by providing suitable reaction backing or metal harness therefor, as shown on the plans or specified herein."

placed between solid ground and the fitting to be anchored; the area of bearing on the pipe and on the ground in each instance shall be that shown or directed by the engineer. The backing shall, unless otherwise shown or directed, be so placed that the pipe and fitting joints will be accessible for repair. *See* Addendum Sec. 12.3.

Sec. 12.4—Metal Harness

Metal harness of tie rods or clamps of adequate strength to prevent movement may be used instead of concrete backing, as directed by the engineer. Steel rods or clamps shall be galvanized or otherwise rustproof treated, or shall be painted as shown or directed by the engineer. *See* Addendum Sec. 12.4.

Section 13—Hydrostatic Tests

Sec. 13.1—Hydrostatic Tests Required

See Addendum Sec. 13.1.

Sec. 13.2—Pressure Test

After the pipe has been laid and partially backfilled as specified in Sec. 14.5, all newly laid pipe, or any valved section thereof, shall be subjected to the hydrostatic pressure stated in Addendum Sec. 13.2. If specified in Addendum Sec. 13.11, or if directed by the engineer, the contractor shall backfill the trench in accordance with Sec. 14.7 before making the pressure test. *See* Sec. 13.11.

Sec. 13.3—Duration of Pressure Test

The duration of each pressure test shall be at least one hour.

Sec. 13.4—Procedure

Each valved section of pipe shall be slowly filled with water and the specified test pressure, based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gage, shall be applied by means of a pump connected to the pipe in a manner satisfactory to the engineer. The pump, pipe connection and all necessary apparatus except gages shall be furnished by the contractor. The owner will furnish the gages for the test and will make all taps into the pipe, but the contractor shall furnish all necessary assistance for conducting the tests.

Sec. 13.5—Expelling Air Before Test

Before applying the specified test pressure, all air shall be expelled from the pipe. If hydrants or blowoffs are not available at high places, the owner shall make the necessary taps at points of highest elevation before the test is made and insert the plugs after the test has been completed.

Sec. 13.6—Examination Under Pressure

All exposed pipes, fittings, valves, hydrants and joints will be carefully examined during the open-trench test. When the joints are made with lead, all such joints showing visible leaks shall be recalked until tight. When the joints are made with cement and show seepage or slight leakage, such joints as may be defective shall be cut out and replaced by the contractor as directed by the engineer. Any cracked or defective pipes, fittings, valves or hydrants discovered in consequence of this pressure test shall be removed and replaced by the contractor with sound

material in the manner provided under Sec. 3, and the test shall be repeated until satisfactory to the engineer.

Sec. 13.7—Leakage Test

A leakage test shall be conducted after the pressure test has been satisfactorily completed. The owner will furnish the gage and measuring device for the leakage test. The contractor shall furnish the pump, pipe, connections and all other necessary apparatus, and shall furnish all necessary assistance to conduct the test. The duration of each leakage test shall be two hours, and during the test the main shall be subjected to the pressure stated in Addendum Sec. 13.7.

Leakage is defined as the quantity of water to be supplied into the newly laid pipe, or any valved section thereof, necessary to maintain the specified leakage test pressure after the pipe has been filled with water and the air expelled.

No pipe installation will be accepted until the leakage is less than the number of gallons per hour as determined by the formula:

$$L = \frac{ND\sqrt{P}}{1{,}850}$$

in which L equals the allowable leakage, in gallons per hour; N is the number of joints in the length of pipeline tested; D is the nominal diameter of the pipe, in inches; and P is the average test pressure during the leakage test, in pounds per square inch gage. (The allowable leakage according to the formula is equivalent to 70 U.S. gal. per 24 hours per mile of pipe per inch nominal diameter, for pipe in 12-ft. lengths evaluated on a pressure basis of 150 psi.)

The allowable leakage at various pressures for pipe of various diameters is shown in Table 1.

Sec. 13.8—Variation From Permissible Leakage

Should any test of pipe laid disclose leakage greater than that specified in Section 13.7, the contractor shall at his own expense locate and repair the defective joints until the leakage is within the specified allowance.

Sec. 13.9—Time for Making Test of Lead-jointed Pipe

Lead-jointed pipe may be subjected to hydrostatic pressure and inspected and tested for leakage at any convenient time after the trench has been partially backfilled except at the joints in accordance with Sec. 14.6, or backfilled in accordance with Sec. 14.7, if specified or directed by the engineer (*see* Sec. 13.11). The leakage allowance shall be that specified in Sec. 13.7.

Where any section of a main is provided with concrete reaction backing, the hydrostatic pressure test shall not be made until at least five days have elapsed after the concrete reaction backing was installed. If high early-strength cement is used in the concrete reaction backing, the hydrostatic pressure test shall not be made until at least two days have elapsed.

Sec. 13.10—Time for Making Test of Cement-jointed Pipe

Pipes jointed with cement shall not be subjected to hydrostatic pressure and inspected and tested for leakage until at least 36 hours have elapsed after the main was filled with water as specified in Sec. 9.16. Pipelines shall remain full of water until all tests have been made. The pressure test, inspection and leakage test shall be made

TABLE 1

Allowable Leakage for Various Pressures and Pipe Diameters

Avg. Test Pressure *psi.*	Allowable Leakage per 100 Joints—*gph.* (U.S.)*																	
	Pipe Diameter—*in.*																	
	2	3	4	6	8	10	12	14	16	18	20	24	30	36	42	48	54	60
150	1.33	1.99	2.65	3.97	5.30	6.62	7.94	9.27	10.59	11.92	13.24	15.89	19.86	23.83	27.81	31.78	35.75	39.72
145	1.30	1.95	2.60	3.91	5.21	6.51	7.81	9.11	10.41	11.72	13.02	15.62	19.53	23.43	27.34	31.24	35.15	39.05
140	1.28	1.92	2.56	3.84	5.12	6.40	7.68	8.95	10.23	11.51	12.79	15.35	19.19	23.03	26.86	30.70	34.54	38.38
135	1.25	1.88	2.51	3.77	5.02	6.28	7.54	8.79	10.05	11.30	12.56	15.07	18.84	22.61	26.38	30.15	33.92	37.68
130	1.25	1.85	2.47	3.70	4.93	6.16	7.40	8.63	9 86	11.09	12.33	14.79	18.49	22.19	25.89	29.58	33.28	36.98
125	1.21	1.81	2.42	3.63	4.84	6.04	7.25	8.46	9.67	10.88	12.09	14.50	18.13	21.76	25.38	29.01	32.64	36.26
120	1.18	1.78	2.37	3.55	4.74	5.92	7.11	8.29	9.47	10.66	11.84	14.21	17.76	21.32	24.87	28.42	31.97	35.53
115	1.16	1.74	2.32	3.48	4.64	5.80	6.96	8.12	9.28	10.43	11.59	13.91	17.39	20.87	24.35	27.82	31.30	34.78
110	1.13	1.70	2.27	3.40	4.54	5.67	6.80	7.94	9.07	10.20	11.34	13.61	17.01	20.41	23.81	27.21	30.61	34.02
105	1.11	1.66	2.22	3.32	4.43	5.54	6 65	7.75	8.86	9.97	11.08	13.29	16.62	19.94	23.26	26.59	29.91	33.23
100	1.08	1.62	2.16	3.24	4.32	5.41	6.49	7.57	8.65	9.73	10.81	12.97	16.22	19.46	22.70	25.95	29.19	32.43
95	1.05	1.58	2.11	3.16	4.22	5.27	6.32	7.38	8.43	9.48	10.54	12.64	15.81	18.97	22.13	25.29	28.45	31.61
90	1.02	1.54	2.05	3.08	4.10	5.13	6.15	7.18	8.21	9.23	10.26	12.31	15.38	18.46	21.54	24.61	27.69	30.77
85	0.99	1.50	1.99	2.99	3.99	4.98	5.98	6.98	7.97	8.97	9.97	11.96	14.95	17.94	20.93	23.92	26.91	29.90
80	0.96	1.45	1.93	2.90	3.87	4.84	5.80	6.77	7.74	8.70	9.67	11.60	14.50	17.41	20.31	23.21	26.11	29.01
75	0.93	1.40	1.87	2.81	3.75	4.68	5.62	6.55	7.49	8.43	9.36	11.24	14.04	16.85	19.66	22.47	25.28	28.09
70	0.90	1.36	1.81	2.71	3.62	4.52	5.43	6.33	7.24	8.14	9.05	10.85	13.57	16.28	18.99	21.71	24.42	27.14
65	0.87	1.31	1.74	2.61	3.49	4.36	5.23	6.10	6.97	7.84	8.72	10.46	13.07	15.69	18.30	20.92	23.53	26.15
60	0.83	1.26	1.67	2.51	3.35	4.19	5.02	5.86	6.70	7.54	8.37	10.05	12.56	15.07	17.59	20.10	22.61	25.12
55	0.80	1.20	1.60	2.41	3.21	4.01	4.83	5.61	6.41	7.22	8.02	9.62	12.03	14.43	16.84	19.24	21.65	24.05
50	0.76	1.15	1.53	2.29	3.06	3.82	4.59	5.35	6.12	6.88	7.64	9.17	11.47	13.76	16.05	18.35	20.64	22.93
45	0.72	1.09	1.45	2.18	2.90	3.63	4.35	5.08	5.80	6.53	7.25	8.70	10.88	13.05	15.23	17.41	19.58	21.76

* If the Imperial gallon is used the figures must be reduced one-sixth.

The allowable leakage for a pipeline is calculated by multiplying the leakage per hour per 100 joints at the average test pressure and for the diameter of pipe tested as obtained from the above table, by the duration of the test in hours and the total number of joints in the line divided by 100. If the section under test contains joints of various diameters, the allowable leakage will be the sum of the computed leakage for each size of joint.

after the trench has been partially backfilled except at the joints in accordance with Sec. 14.6, or backfilled in accordance with Sec. 14.7, if specified or directed by the engineer (*see* Sec. 13.11). The leakage allowance shall be that specified in Sec. 13.7.

Where any section of a main is provided with concrete reaction backing, the hydrostatic pressure test shall not be made until at least five days have elapsed after the concrete reaction backing was installed. If high early-strength cement is used in the concrete reaction backing, the hydrostatic pressure test shall not be made until at least two days have elapsed.

Sec. 13.11—Pressure and Leakage Tests After Backfilling

After the trench has been backfilled in accordance with Sec. 14.7, the test connections made and the main filled with water, the test sections shall be subjected to water pressure normal to the area. After examination of exposed parts of the system, the test pressure will be increased to the hydrostatic pressure specified in Addendum Sec. 13.2 and exposed parts again examined. If defects are found, the contractor shall immediately make the necessary repairs at his own expense. The engineer will then repeat the pressure test until no defects are found. The duration of the final pressure test shall be at least one hour.

The leakage test shall be conducted after satisfactory completion of the pressure test, in accordance with Sec. 13.7. Should any test section fail to meet the leakage test, the contractor shall make the necessary repairs at his own expense. *See* Addendum Sec. 13.11.

Section 14—Backfilling

Sec. 14.1—Backfill Material

All backfill material shall be free from cinders, ashes, refuse, vegetable or organic material, boulders, rocks or stones, or other material which in the opinion of the engineer is unsuitable. However, from 1 ft. above the top of the pipe to the subgrade of the pavement, material containing stones up to 8 in. in their greatest dimension may be used, unless specified otherwise herein.

Sec. 14.2—Use of Excavated Material as Backfill

When the type of backfill material is not indicated on the drawings or specified, the contractor may backfill with the excavated material, provided that such material consists of loam clay, sand, gravel or other materials which, in the opinion of the engineer, are suitable for backfilling. Where excavated material is indicated on the drawings or specified for backfill and there is a deficiency due to a rejection of part thereof, the contractor shall furnish the required amount of sand, gravel or other approved material as an extra.

Sec. 14.3—Sand or Gravel Backfill

Where sand or gravel backfill is not indicated on the drawings or specified herein, and in the opinion of the engineer should be used in any part of the work, the contractor shall furnish and backfill with sand or gravel as directed as an extra.

various diameters, the allowable leakage will be the sum of the computed leakage for each size of joint.

Sec. 14.4—Limestone Screenings Backfill

Where shown on the drawings or specified in the Addendum, or where directed by the engineer, the contractor shall completely encase the pipe, fittings and appurtenances in limestone screenings 1 ft. thick and complete the backfilling of the trench as shown or directed by the engineer. The limestone screenings shall be placed in layers 3 in. thick and compacted by tamping to the bottom of the trench at subgrade as required in Sec. 6.7 if blocking is not used, and to about 1 in. below the subgrade as required in Sec. 6.10 if blocking is used. Above these elevations the limestone screenings shall be placed in layers 3 in. thick and compacted by tamping under the pipe, fittings and appurtenances to the centerline, as required in Sec. 14.5. From the centerline to 1 ft. above the pipe, fittings and appurtenances, the limestone screenings shall be placed as specified in Addendum Sec. 14.4. The contractor shall be allowed extra compensation for excavating, furnishing and placing the limestone screenings where such work is not shown on the drawings or specified. *See* Note 14.4 *and* Addendum Sec. 14.4.

Sec. 14.5—Backfilling Under Pipe

All trenches—whether the pipe, fittings and appurtenances are laid on a flat bottom at subgrade in accordance with Sec. 6.5 or laid on blocking in accordance with Sec. 6.10—shall be backfilled by hand, from the bottom of the trench to the centerline of the pipe, with sand, gravel or other approved material placed in layers of 3 in. and compacted by tamping. Backfilling material shall be deposited in the trench for its full width on each side of the pipe, fittings and appurtenances simultaneously.

Sec. 14.6—Backfilling Over Pipe

From the centerline of the pipe, fittings and appurtenances to a depth of 1 ft. above the top of the pipe, the trench shall be backfilled by hand or by approved mechanical methods. The contractor shall use special care in placing this portion of the backfill so as to avoid injuring or moving the pipe. See Addendum Sec. 14.6 for the type of backfill material required and the method of placing and consolidating.

Sec. 14.7—Backfilling to Grade

From 1 ft. above the pipe to the grade shown on the drawings or specified herein, the trench shall be backfilled by hand or by approved mechanical methods. See Addendum Sec. 14.7 for the type of backfill required and the method of placing and consolidating.

Sec. 14.8—Backfill Under Permanent Pavement

Where the excavation is made through permanent pavements, curbs, driveways or sidewalks or where such structures are undercut by the excavation, the entire backfill to the subgrade of the structures shall be made with sand. Walks and driveways consisting of broken stone, gravel, slag or cinders shall not be considered as being of a permanent construction. See Addendum Sec. 14.8 for the method of placing and consolidating the backfill material.

Sec. 14.9—Backfilling Where Settlement Unimportant

Where shown on the drawings or specified, the contractor may backfill the trench from 1 ft. above the pipe to the top of the trench with the excavated material, and the backfill shall be neatly rounded over the trench to a sufficient height to allow for settle-

ment to grade after consolidation. See Addendum Sec. 14.9.

Sec. 14.10—Backfilling in Freezing Weather

Backfilling shall not be done in freezing weather except by permission of the engineer, and it shall not be made with frozen material. No fill shall be made where the material already in the trench is frozen.

Sec. 14.11—Backfill Sand

All sand used for backfill shall be a natural bank sand, graded from fine to coarse, not lumpy or frozen, and free from slag, cinders, ashes, rubbish or other material which, in the opinion of the engineer, is objectionable or deleterious. It shall not contain a total of more than 10 per cent by weight of loam and clay, and all material must be capable of being passed through a ¾-in. sieve. Not more than 5 per cent shall remain on a No. 4 sieve.

Sec. 14.12—Backfill Gravel

Gravel used for backfill shall consist of natural bank gravel having durable particles graded from fine to coarse in a reasonably uniform combination with no boulders or stones larger than 2 in. in size. It shall be free from slag, cinders, ashes, refuse or other deleterious or objectionable materials. It shall not contain excessive amounts of loam and clay and shall not be lumpy or frozen. No more than 15 per cent shall be finer than No. 200 sieve.

Sec. 14.13—Backfill Limestone Screenings

Screenings shall consist of the product obtained from crushing sound limestone or dolomite ledge rock and shall be free from shale, dust, excessive amounts of clay and other undesirable materials. All materials shall pass a ½-in. sieve and no more than 25 per cent shall be finer than a No. 100 sieve.

Section 15—Removal, Restoration and Maintenance of Surface

Sec. 15.1—Allowable Removal of Pavement

The contractor shall remove pavement and road surfaces as a part of the trench excavation, and the amount removed shall depend upon the width of trench specified for the installation of the pipe and the width and length of the pavement area required to be removed for the installation of gate valves, specials, manholes or other structures. The width of pavement removed along the normal trench for the installation of the pipe shall not exceed the width of the trench specified by more than 6 in. on each side of the trench. The width and lengths of the area of pavement removed for the installation of gate valves, specials, manholes or other structures shall not exceed the maximum linear dimensions of such structures by more than 6 in. on each side. Wherever, in the opinion of the engineer, existing conditions make it necessary or advisable to remove additional pavement, the contractor shall remove it as directed by the engineer and shall receive extra compensation therefor, provided such additional work is not shown in the drawings or specified. The contractor shall use such methods, either drilling or chipping, as will assure the breaking of the pavement along straight lines. The face of the remaining pavement shall be approximately vertical. *See* Addendum Sec. 15.1.

If the contractor removes or damages pavement or surfaces beyond the limits specified above, such pavement

and surfaces shall be replaced or repaired at the expense of the contractor as specified in Sec. 15.2.

Sec. 15.2—Restoration of Damaged Surfaces and Property

Where any pavement, trees, shrubbery, fences, poles or other property and surface structures have been damaged, removed or disturbed by the contractor, whether deliberately or through failure to carry out the requirements of the contract documents, state laws, municipal ordinances or the specific direction of the engineer, or through failure to employ usual and reasonable safeguards, such property and surface structures shall be replaced or repaired at the expense of the contractor. If Addendum Sec. 15.3 specifies that the replacements or repairs shall be made by the contractor, he shall replace or repair and restore said structures to a condition equal to that before the work began, furnishing all labor and materials incidental thereto. If Addendum Sec. 15.4 specifies that the replacement or repairs will be made by the owner, the cost of the replacements or repairs will be deducted from monies due the contractor. Costs shall be determined by the engineer from measurements and the cost of replacement or repairs, or from a schedule of fixed charges previously prepared by the owner and furnished the contractor. *See* Addendum Sec. 15.2.

Sec. 15.3—Replacement of Pavement and Structures by Contractor

The contractor shall restore (unless otherwise stipulated) all pavement, sidewalks, curbing, gutters, shrubbery, fences, poles, sod or other property and surface structures removed or disturbed as a part of the work to a condition equal to that before the work began, furnishing all labor and materials incidental thereto. In restoring the pavement, sound granite blocks, sound brick or asphalt paving blocks may be reused. No permanent pavement shall be restored unless and until, in the opinion of the engineer, the condition of the backfill is such as to properly support the pavement. *See* Addendum Sec. 15.3.

Sec. 15.4—Replacement of Pavement and Structures by Owner

The owner will restore (unless otherwise stipulated) all pavements, sidewalks, curbing, gutter, shrubbery, fences, poles, sod or other property and surface structures removed or disturbed as a part of the work. *See* Addendum Sec. 15.4.

Sec. 15.5—Cleaning up

All surplus water main materials furnished by the contractor and all tools and temporary structures shall be removed from the site by the contractor. All dirt, rubbish and excess earth from the excavation shall be hauled to a dump provided by the contractor and the construction site left clean to the satisfaction of the engineer. All surplus water main materials furnished by the owner and delivered to the site by the contractor shall be removed and delivered by the contractor to a location designated by the owner. All surplus water main material furnished and delivered by the owner shall be removed by the owner.

Sec. 15.6—Maintenance of Surface

See Addendum Sec. 15.6.

NOTES

The boldface numerals at the beginning of each note refer to the section of the specification to which the note relates.

5.2. In a specification of this kind it is not possible to set forth the rights and responsibilities of the owner and of the utilities and others owning structures that may have to be removed, relocated or reconstructed, because such rights and responsibilities vary in different localities. Then, too, the owners of certain structures may insist on doing all or part of the work involved at the expense of the owner installing the water main. It is recommended that an investigation be made when the plans are prepared and the rights and responsibilities of all parties involved be considered in allocating the work to be done. When obstructions not shown on the plans are encountered during the progress of the work, the rights and responsibilities of the parties involved will also determine the allocation of the work and costs.

5.5. The minimum depth of cover over water pipe should be determined by: [1] the maximum depth of frost penetration in the locality where the pipe is to be laid and [2] the direct effect of loaded trucks.

The depth of cover and the nature of the trench bottom are two primary factors in the determination of metal thicknesses. Metal thicknesses, as developed from calculations by the American Standards Assn. Committee A21, take into account four distinct trench conditions and two types of backfill and varying depth of cover. A cover of about 4 ft. with a flat-bottom trench and tamped backfill usually results in the most favorable combination of earth and truck hazard.

Where failures in cast-iron pipelines occur, they usually result from settlement, careless laying, flat-slope trenching, bedding on rock, improper backfilling procedure, impact from loaded trucks or rupture from freezing because of shallow cover. These and other external and internal hazards should be carefully considered before the line is laid.

For full details of the design of cast-iron pipe for various pressures and trench conditions, refer to findings of American Standards Assn. Committee A21 on Specifications for Cast-Iron Pipe.

6.2. The width of trench will depend upon and vary with the size of the pipe, the depth of the trench and the nature of the excavated material encountered. However, it should provide for the minimum removal and replacement of pavement consistent with the requirements of Sec. 6.2.

The minimum widths shown in Table 2 represent the best judgment obtainable thereon for use where the soil is fairly stable and for depths of trench varying from about 6 to 12 ft. For each size of pipe, the minimum widths of earth shown provide a clearance of about 4 in. on each side of the bell of the pipe.

Where shallow trenches are used, the widths may be less than those shown in the table.

6.5(a). The type of pipe foundation described in Sec. 6.5 is preferable to the alternative specified under Sec. 8—Blocking. Experiments indicate that the walls of the pipe supported by blocks must be thicker than one laid in a flat-bottom trench, in order to stand the same internal pressure and external loads. There appears to be

TABLE 2
Minimum Trench Widths

Nom Pipe Diam. *in.*	Minimum in Earth *in.*	Minimum in Rock *in.*
2	18	24
3	18	24
4	18	24
6	21	24
8	24	24
10	26	26
12	28	28
18	31	31
20	33	33
24	36	36
30	40	40
36	47	47
42	54	54
48	61	61
54	68	68
60	75	75

no doubt that the bearing strength of pipe laid in a flat-bottom trench, well tamped or puddled, is considerably greater than if the pipe is laid and continues to bear on blocking. Consideration must be given to the type of trench, method of backfilling and use of blocks, if any, when specifying the metal thickness of pipe required in any particular installation.

Other factors affecting pipe thickness—such as water hammer, excessive earth loads, truck loads, foundry tolerance and corrosion—should also be considered. For full details of the design of cast-iron pipe for various pressures and trench conditions, refer to findings of American Standards Assn. Committee A21 on Specifications for Cast-Iron Pipe. From these findings, blocking, if used, should be recognized as a temporary expedient and the load should be transferred to the soil tamped under the pipe as soon as possible.

6.5(b). Excavating to the grade line is recommended when the soil at subgrade is uniformly good, and stones, dry clay, hard pan, shale or cemented gravel are not exposed.

6.6. Excavating below the grade line and backfilling is recommended when the soil at subgrade is not uniformly good, and stones, dry clay, hard pan, shale or cemented gravel are exposed. In some localities, this procedure is followed even when the soil at subgrade is uniformly good, in order to eliminate the final trimming of the trench bottom by hand, improve drainage conditions and obtain more rapid progress.

7.8. The deflection of a pipeline may be obtained by opening the joints, thereby permitting one side of the spigot end of the pipe to be away from home when the other side is touching the hub of the bell. However, an adequate depth of jointing material should always be provided on the side where the spigot is away from home, and an adequate width of calking space on the opposite side of the pipe at the face of the bell.

The maximum deflections shown in Table 3 recognize the limitations which should be observed when deflecting cast-iron bell-and-spigot pipe.

8.3. The number and size of blocks for various sizes and lengths of pipe shown in Table 4 represent a practice used satisfactorily in some localities.

9a. Other materials have been extensively used in the jointing of cast-iron pipe. Pending the completion of an investigation of the performance of sulfur jointing compounds, these materials are not included in the specifications. Directions covering their use are herewith included, for the guidance of those who may employ these materials. These directions are reprinted from the 1938 Specifications for Lay-

TABLE 3—*Maximum Deflections of Cast-Iron Bell-and-Spigot Pipe**

Nom. Pipe Diam.	Joint Opening	Max. Deflection With Pipe Length of:				Approx. Radius of Curve Produced by Succession of Joints With Pipe Lengths of:			
		12 ft.	16 ft.	18 ft.	20 ft.	12 ft.	16 ft.	18 ft.	20 ft.
	in.					ft.			
2	0.41	23.6	31.5	35.4	39.4	73	98	110	122
3	0.43	14.8	19.7	22.2	24.7	112	149	168	186
4	0.41	11.1	14.8	16.7	18.5	156	208	234	260
6	0.58	11.1	14.8	16.7	18.5	156	208	234	260
8	0.65	9.7	12.9	14.6	16.2	178	238	268	297
10	0.75	9.3	12.4	14.0	15.5	186	248	279	310
12	0.75	7.9	10.5	11.9	13.2	218	292	327	363
14	0.75	6.7	8.9	10.1	11.2	258	345	387	430
16	0.75	5.9	7.9	8.8	9.7	293	390	440	488
18	0.75	5.3	7.1	8.0	8.8	326	434	489	543
20	0.75	4.8	6.4	7.2	8.0	360	480	540	600
24	0.75	4.0	5.3	6.0	6.7	432	577	648	720
30	0.75	3.3	4.4	5.0	5.5	524	699	786	873
36	0.75	2.8	3.7	4.2	4.7	617	824	926	1,028
42	0.75	2.4	3.2	3.6	4.0	720	960	1,080	1,200
48	0.75	2.1	2.8	3.2	3.5	823	1,097	1,234	1,371
54	0.75	1.9	2.5	2.9	3.2	909	1,211	1,364	1,515
60	0.75	1.7	2.3	2.6	2.8	1,016	1,355	1,524	1,695

* Limiting factors: [1] joint opening not to exceed 0.75 in.; [2] calking space at face of bell to be not less than 0.25 in. in width.

TABLE 4—*Number and Size of Blocks*

Pipe id. in.	No. of Blocks Required		Block Dimensions*—in.		
	2-ft. Length or Less	Over 12-ft. Length	Thickness	Width	Length
2	1	2	2	6	8
3	1	2	2	6	9
4	1	2	2	6	10
6	1	2	2	6	12
8	1	2	2	6	14
10	1	2	2	6	16
12	1	2	2	6	18
16	1	2	4	6	22
18	2	2	4	6	24
20	2	2	4	6	26
24	2	2	4	6	30
30	2	2	4	6	36
36	2	2	6	6	42
42	2	2	6	6	48
48	2	2	6	8	54
54	2	2	6	8	60
60	2	2	6	8	66

* Wedges should be 2 × 2 × 6 in. long. Larger-sized blocks should be used where necessary to support valves and fittings.

ing Cast-Iron Pipe, prepared and published by the A.W.W.A.:

Sec. 10.5—Sulfur Compound Joints: Compound for pipe joints shall be of approved make and of established reputation. It shall have a sulfur base and other ingredients properly proportioned to produce a workable compound, and tight and permanent joints.

10.51 *Manufacturer's Instructions to Be Followed:* The compound shall be heated in a melting furnace suitable for the use of sulfur compound and manipulated in accordance with the instructions of the manufacturer of the compound.

10.52 *Proper Condition for Pouring:* It shall be stirred thoroughly and continuously while melting, and until used. When poured it must be very liquid, free from froth or bubbles or any foreign matter and shall show a mirror-like surface.

10.53 *Making the Joint:* Suitable funnel-shaped metal pouring gates extending not less than 8 in. above the bell shall be adequately clayed to the joint runner. The joint space and gate shall be filled with one continuous pour while the compound is at the proper temperature. The solidified compound in the pouring gate shall be cut off flush with the top of the bell or broken off flush with the top of the joint.

10.54 *Replacing Defective Joints:* If a joint is defective, it shall be cut out and entirely replaced as directed by the engineer.

10.55 *Burned Compound Rejected:* Any compound burned in the melting pot shall be dumped out and not reused.

9a.9. It is the practice in certain localities where cement joints are used to install some lead joints in the main to relieve possible strains on fittings or valves that might result from the extreme rigidity of a cement-jointed pipeline and also to speed up the completion of the final connections of a line in order to get it into service. One lead joint is poured at every gate valve, at every fire hydrant lateral and at intervals of about 500 ft. in a long line without valves or fittings. Sometimes two or three lead joints are poured for speed in completing the final connections. A lead joint at a fire hydrant may permit a twisting or deflecting of the connection when the hydrant is struck by an automobile instead of resulting in a broken hydrant.

9b.4. For the convenience of those interested, a list of suppliers of torque wrenches, taken from *MacRae's Blue Book,* is given below:

Ammco Tools, Inc.
2124 Commonwealth Ave.
North Chicago, Ill.

Apco-Mossberg Co.
Attleboro, Mass.

Armstrong Bros. Tool Co.
5211 W. Armstrong Ave.
Chicago 30, Ill.

Blackhawk Mfg. Co.
5325 W. Rogers St.
Milwaukee 1, Wis.

The Herbrand Corp.
Fremont, Ohio

J. O. Mfg. Co.
South Gate, Calif.

P. & C. Hand Forged Tool Co.
Box 5926
Milwaukie P.O.
Portland 22, Ore.

Reasor Mfg. Co.
St. Charles, Ill.

Richmont, Inc.
922-M S. Myrtle Ave.
Monrovia, Calif.

Snap-On Tools Corp.
8031—28th Ave.
Kenosha, Wis.

Stevens Walden, Inc.
475 Shrewsbury St.
Worcester, Mass.

Sturtevant Co.
Addison, Ill.

Sunnen Products Co.
7954 Manchester Ave.
St. Louis 17, Mo.

Sweeney Mfg. Co.
1601—23rd St.
Denver 17, Colo.

Williams & Co.
400 Vulcan St.
Buffalo, N. Y.

11.4. Proper drainage of waste water from a hydrant is very important where there is a possibility of the water freezing in the barrel of the hydrant, and where this may occur a drainage system that will dispose of the waste water rapidly should be used. Where ground water may enter the hydrant through the waste openings and contaminate the water supply, it is recommended that the waste openings be plugged and the waste water removed from the barrel immediately after the hydrant has been used.

12.2. Section 12.2 does not apply to suction pipelines or, at the discretion of the engineer, to low-pressure pipelines less than 12 in. in diameter.

14.4. It is considered good practice to encase the pipe, fittings and appurtenances in limestone screenings when muck, ash, refuse, cinders or acid soil is encountered in the excavation.

SPECIAL NOTE

Disinfection of Water Mains

The disinfection of newly laid water mains is not included in these specifications because usually the owner is better equipped to do the work and because the amount of the work involved cannot be estimated.

It is recommended that upon completion of a newly laid main or when repairs to an existing line are made, the main be disinfected according to "A Procedure For Disinfecting Water Mains—AWWA C601."

OUTLINE OF ADDENDUM

If the Specifications in their published form are to be used, the engineer should prepare and include as a part of the Specifications an addendum, entitled "Addendum to the Specifications for Installation of Cast-Iron Water Mains." Since the specifications include the various standard materials that may be used and the several standard methods that may be followed, the engineer should select the materials and methods that apply to the project and, by reference to the sections in the Specifications, indicate in the addendum those which do or do not apply.

The engineer should include in the addendum information pertaining to subject matter referred to in certain sections of the Specifications which cannot therein be completely covered and made applicable to all projects. The engineer may also include in the addendum information to cover work and materials not included in the Specifications.

The following is a guide to aid the engineer in preparing the addendum. (The section and paragraph numbers below correspond to the related sections of the Specifications.)

Sec. 1—Scope

1.3—General Description of Work to Be Done. The work to be done under these specifications consists of laying approximately ..... linear feet of .....-inch water main in ..... Street from ..... Street to ..... Street.

NOTE: The engineer should include a general description of the work to be done and the location of the work. A suitable breakdown of the work to be done is desirable.

1.4—Schedule of Progress and Completion. The work in ..... Street shall be started by ....., 19..... and shall be completed by ....., 19.....

NOTE: If various parts of the work are to be started and completed at different times, the engineer should include a suitable breakdown.

1.5—List of Contract Drawings. The contract drawings which apply to these Specifications and Addendum are listed below:

Drawing No.	Title	File No.
.....	.....	.....
.....	.....	.....

1.6—Special Work to Be Performed.

NOTE: The engineer should specify any special work required which is not covered by the Specifications for Installation of Cast-Iron Water Mains. It may include a section of pipe other than cast-iron and laid under another AWWA specification, or other structures covered by specifications prepared by the engineer. If no special work is required, it should be so stated.

1.7—Materials to Be Furnished by Owner. The owner will furnish the following materials:

No. of Pieces	Class	Description	Approx. Weight	Delivery Point
.....	.....	.....	.....	.....
.....	.....	.....	.....	.....

NOTE: The engineer should also specify what materials, if any, are to be unloaded by the contractor from railroad cars. If no materials are to be furnished by the owner, the engineer should so specify.

1.8—Materials to Be Furnished by Contractor. The following is a partial estimate of materials to be furnished and delivered by the contractor:

No. of Pieces	Class	Description	Approx. Weight
.....	.....	.....	.....
.....	.....	.....	.....

NOTE: The engineer should include all materials required and not furnished by the owner.

1.9—Water Used. Water for testing mains, puddling trenches and drinking purposes will be made available to the contractor at the existing facilities of the owner at a charge of ..... The contractor shall furnish all necessary pipe or hose extensions or transportation to the point of use. The contractor shall exercise care in the use of the water.

NOTE: If the water is to be furnished by the owner without charge, or if the contractor is to furnish the water at his expense, it should be so stated in lieu of the above requirement.

Sec. 2—Inspection

2.1—Shop Inspection. The inspection at the plant of the manufacturer of materials furnished by the contractor shall be made at the expense of the owner or contractor.

NOTE: The engineer should include a list of the materials furnished by the contractor and subject to inspection at the plant of the manufacturer and state whether the inspection shall be made at the expense of the owner or contractor.

Sec. 4—Handling of Material

4.1—Hauling. The contractor shall pick up the materials furnished by the owner, as set forth in Sec. 1.7 of the Addendum, at the delivery points specified, haul the materials to and distribute them at the site.

NOTE: If the materials furnished by the owner are not to be picked up, hauled to and distributed at the site by the contractor, this should be stated. If part of the material furnished by the owner is to be handled by the contractor, the engineer should here list these materials in a table similar to the one included in Sec. 1.7 of the Addendum.

Sec. 5—Alignment and Grade

5.5—Depth of Pipe. The centerline of all pipe shall be laid to a minimum depth of ..... feet ..... inches below established grade.

NOTE: The above specification should only be included if the contract drawings do not show the grade line.

Sec. 6—Excavation and Preparation of Trench

6.1—Description. Not more than ..... linear feet of trench shall be dug in advance of the completed pipe-laying operation.

6.2—Width of Trench. The width of trench for the various sizes of pipe and locations shown shall be as follows:

NOTE: The engineer should here include a table showing the size of pipe and width of trench for various locations.

6.5—Excavation to Grade. The trench shall be excavated in accordance with Sec. 6.5. Sections 6.6 and 6.10 shall not apply, *or*

6.6—Excavation Below Grade. The trench shall be excavated in accordance with Section 6.6. Sections 6.5 and 6.10 shall not apply, *or*

6.10—Subgrade for Blocking. The trench shall be excavated in accordance with Sec. 6.10. Sections 6.5 and 6.6 shall not apply.

NOTE: The engineer should here include one of the above requirements.

Sec. 7—Laying

7.8—Permissible Deflection at Joints. Whenever it is necessary to deflect pipe from a straight line, the deflection shall not exceed the following amounts:

NOTE: The engineer should here include a table showing the maximum permissible deflections.

7.9—Railroad and Street Railway Crossings.

NOTE: The engineer is advised to consult with the railroad or street railway company before preparing plans and specifications for this part of the work. The company may require the work to be done according to a certain procedure and during certain hours. It may insist also upon doing some of the work itself and make charges for labor, material, supplies, supervision and inspection. Furthermore, the company may insist on dealing with the owner. However, whatever, the arrangements may be, they should be agreed upon prior to bidding so that there will be an understanding on how and when the work is to be done, the apportionment of the work and the disposition of the cost and any charges made by the company.

The engineer should here include a specification for the installation of the mains under railroad and street railway crossings in accordance with the plans and procedure agreed upon.

The engineer should also here specify that "Where a main is laid under a single track, it shall be constructed so that the center point of a full length of pipe lies midway between the rails of such single track. Where the main is laid under multiple tracks, it shall be constructed so that the joints lie midway between the tracks."

Sec. 8—Blocking

8.1—Support Required. Blocking as specified in Sec. 8 shall be provided, *or*

Blocking as specified in Sec. 8 shall not be provided.

NOTE: The engineer should here include one of the above requirements.

8.3—Dimensions. The number and size of blocks specified in Sec. 8.3 shall be used.

NOTE: If Sec. 8.3 does not apply, the engineer should here so state and include the number and sizes of blocks that shall be used.

Sec. 9a—Jointing

9a.1—Yarning or Packing Material. The yarning or packing material shall be

---

NOTE: The engineer should here state which material shall be used. If cement joints are used and the yarning or packing material is to be omitted, the engineer should here so specify. If some lead joints are to be used with the cement joints, the engineer should here specify the yarning or packing material that should be used with the lead joints.

9a.4—Lead Joints. All sections pertaining to lead joints shall apply and all sections pertaining to cement joints shall not apply, *or*

9a.9—Cement Joints. All sections pertaining to cement joints shall apply and all sections pertaining to lead joints shall not apply.

NOTE: The engineer should here include one of the above requirements.

Sec. 11—Setting Hydrants

11.4—Hydrant Drainage in Pervious Soil. This section shall apply and Sec. 11.5 shall not apply, *or*

11.5—Hydrant Drainage in Impervious Soil. This section shall apply and Sec. 11.4 shall not apply.

NOTE: The engineer should here specify one of the above requirements. If the soil conditions are not known, the engineer should specify that the type of hydrant drainage will be selected after the excavation of the trench.

Sec. 12—Anchorage

12.1—Anchorage for Hydrants. The anchorage for hydrants shall consist of stone slabs or concrete backing, *or*

The anchorage for hydrants shall consist of metal rods or clamps.

NOTE: The engineer should here specify one of the above requirements.

12.3—Reaction Backing. This section shall apply and Sec. 12.4 shall not apply, *or*

12.4—Metal Harness. This section shall apply and Sec. 12.3 shall not apply.

NOTE: The engineer should here include one of the above requirements.

Sec. 13—Hydrostatic Tests

13.1—Hydrostatic Tests Required. Hydrostatic tests as specified in Sec. 13.2-

13.9 inclusive shall apply for lead joints and Sec. 13.10 shall not apply, *or*

Hydrostatic tests as specified in Sec. 13.2–13.8 inclusive and Sec. 13.10 shall apply for cement joints and Sec. 13.9 shall not apply.

NOTE: The engineer should here include one of the above requirements.

13.2—Pressure Test. The hydrostatic pressure shall be ..... pounds per square inch, based on the elevation of the lowest point in the line or section under test and corrected to the elevation of the test gage.

NOTE: A test pressure 50 per cent above normal operating pressure is considered conservative practice.

13.7—Leakage Test. The hydrostatic pressure shall be ..... pounds per square inch, based on the elevation of the lowest point in the line or section under test and corrected to the elevation of the test gage.

NOTE: The pressure for the leakage test is usually set at the maximum operating pressure for the locality.

13.11—Pressure and Leakage Tests After Backfilling. The contractor shall backfill the trench before making the pressure and leakage tests.

NOTE: The engineer should here include the above requirement if the trench is to be backfilled before the tests are made.

Sec. 14—Backfilling

14.4—Limestone Screenings Backfill. This section shall (*or* shall not) apply.

NOTE: If the drawings show all the locations where limestone screening backfill shall be placed, the engineer should state that this section shall apply. If the drawings do not show all or any of the locations, the engineer should state that this section shall apply and here specify the additional locations or all of the locations. If this section shall not apply, the engineer should so specify.

14.6—Backfilling Over Pipe. The backfill material from the centerline of the pipe to 1 ft. above the pipe shall consist of:

1. Sand which shall be puddled with hose and long pipe nozzle after the trench is backfilled, *or*

2. Gravel which shall be puddled with hose and long pipe nozzle after the trench is backfilled, *or*

3. Approved excavated material which shall be puddled with hose and long pipe nozzle after the trench is backfilled, *or*

4. Approved excavated material which shall be placed in 3-in. layers and compacted by tamping.

NOTE: The engineer should here include one of the above requirements or any other requirement which is to be followed. The type of backfill material and the method of placing and compacting depends upon the importance of settlement. It also depends upon the type of pavement or surface. Puddling should not be done until the trench is backfilled. If more than one type of material and method of backfilling is required, the drawings or the Addendum should indicate the limits of each.

14.7—Backfilling to Grade. The backfill material from 1.0 ft. above the pipe to the street grade (or subgrade of pavement) shall consist of:

1. Sand which shall be puddled with hose and long pipe nozzle after the trench is backfilled, *or*

2. Gravel which shall be puddled with hose and long pipe nozzle after the trench is backfilled, *or*

3. Approved excavated material which shall be puddled with hose and long pipe nozzle after the trench is backfilled, *or*

4. Approved excavated material which shall be placed in 3-in. layers and compacted by tamping.

NOTE: The engineer should here include one of the above requirements or any other requirement which is to be followed. The type of backfill material and the method of placing and compacting depends upon the importance of settlement. It also depends upon the type of pavement or surface. Puddling should not be done until the trench is backfilled. If more than one type of material and method of backfilling is required, the drawings or the Addendum should indicate the limits of each.

14.8—Backfill Under Permanent Pavement. This section shall (*or* shall not) apply.

NOTE: If this section applies, the engineer should here include the method of placing and consolidating.

14.9—Backfilling Where Settlement Unimportant. This section shall (*or* shall not) apply.

NOTE: If this section applies, the engineer should show on the drawings or here include the limits.

Sec. 15—Removal, Restoration and Maintenance of Surface

15.1—Allowable Removal of Pavement.

NOTE: If the requirements of Sec. 15.1 are not applicable, the engineer should so state and prepare requirements that do apply.

15.2—Restoration of Damaged Surfaces and Property. This section shall apply and the cost of the replacement or repairs will be determined by the engineer from measurements and the costs incurred (or from a schedule of fixed charges, or from a combination of both).

NOTE: The engineer should here include a statement showing how the costs will be determined. Some cities do the repaving and restoration of sidewalk, curb, gutter and driveways with their own forces and furnish the bidders with a schedule of fixed unit prices.

15.3—Replacement of Pavement and Structures by Contractor. This section shall (*or* shall not) apply.

NOTE: If the drawings do not show the type of replacement, the engineer should here specify the materials to be used.

15.4—Replacement of Pavement and Structures by Owner. This section shall (*or* shall not) apply.

15.6—Maintenance of Surface. Following the certification of completion by the engineer, the contractor shall maintain the surface of the unpaved trenches, curbs, sidewalks, gutters, shrubbery, fences, sod and other surfaces disturbed for a period of three months thereafter; and shall maintain the repaved areas (if paved by the contractor) and curbs, gutters and sidewalks for one year after said certification.

All material and labor required for the maintenance of the trenches and adjacent structures shall be supplied by the contractor and the work shall be done in a manner satisfactory to the engineer.

NOTE: If the above paragraph does not apply in its entirety, the engineer should prepare a suitable paragraph.

Special Note—Extra Work

The Specifications for Installation of Cast-Iron Water Mains include provisions for payment for extra work in Sec. 5.2, 5.4, 6.5, 6.7, 6.8, 6.10, 6.13, 14.2 and 14.4, and the engineer should include means of measurement and payment for such extra work elsewhere in the contract documents.

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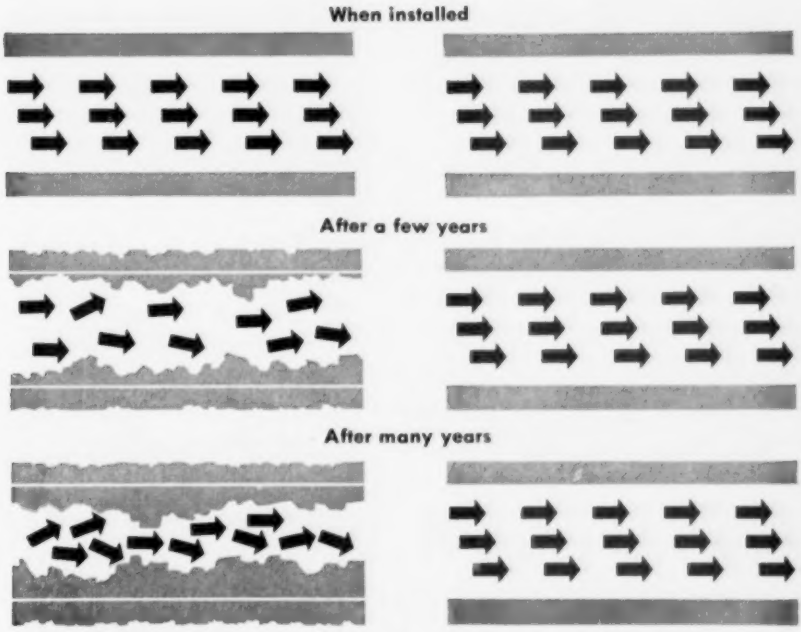

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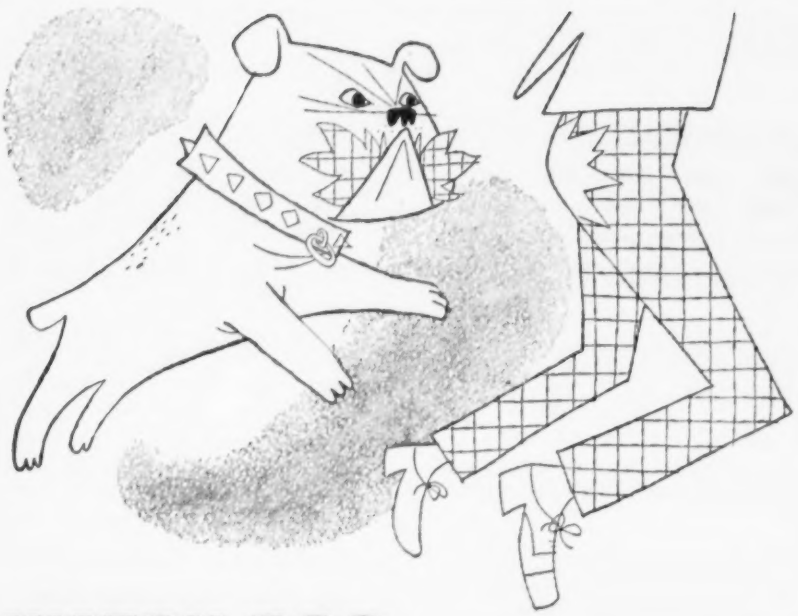

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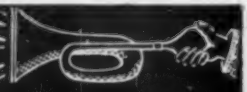

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For over 40 years HYDRO-TITE has been faithfully serving water works men everywhere. Self-caulking, self-sealing, easy-to-use. Costs about 1/5 as much as lead joints. Packed in 100 lb. moisture-proof bags.

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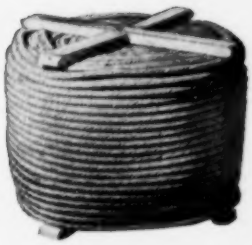

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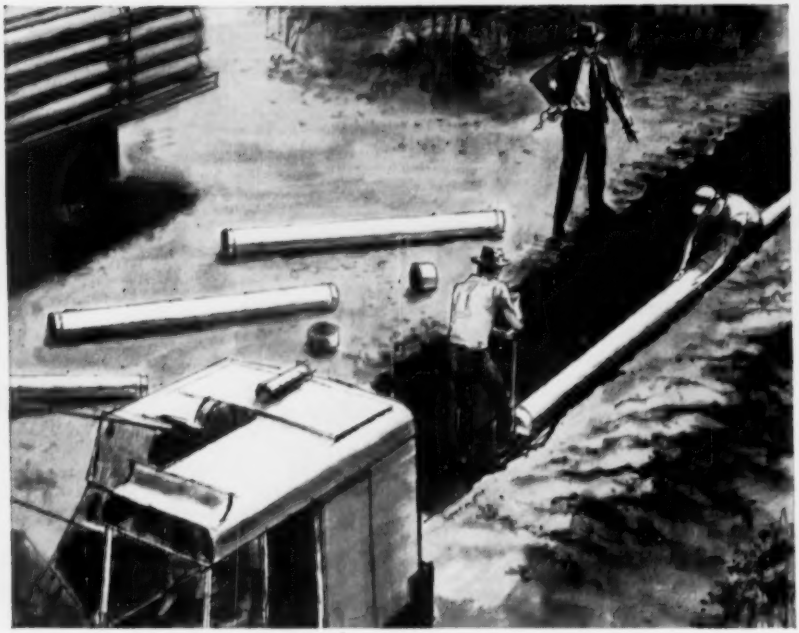

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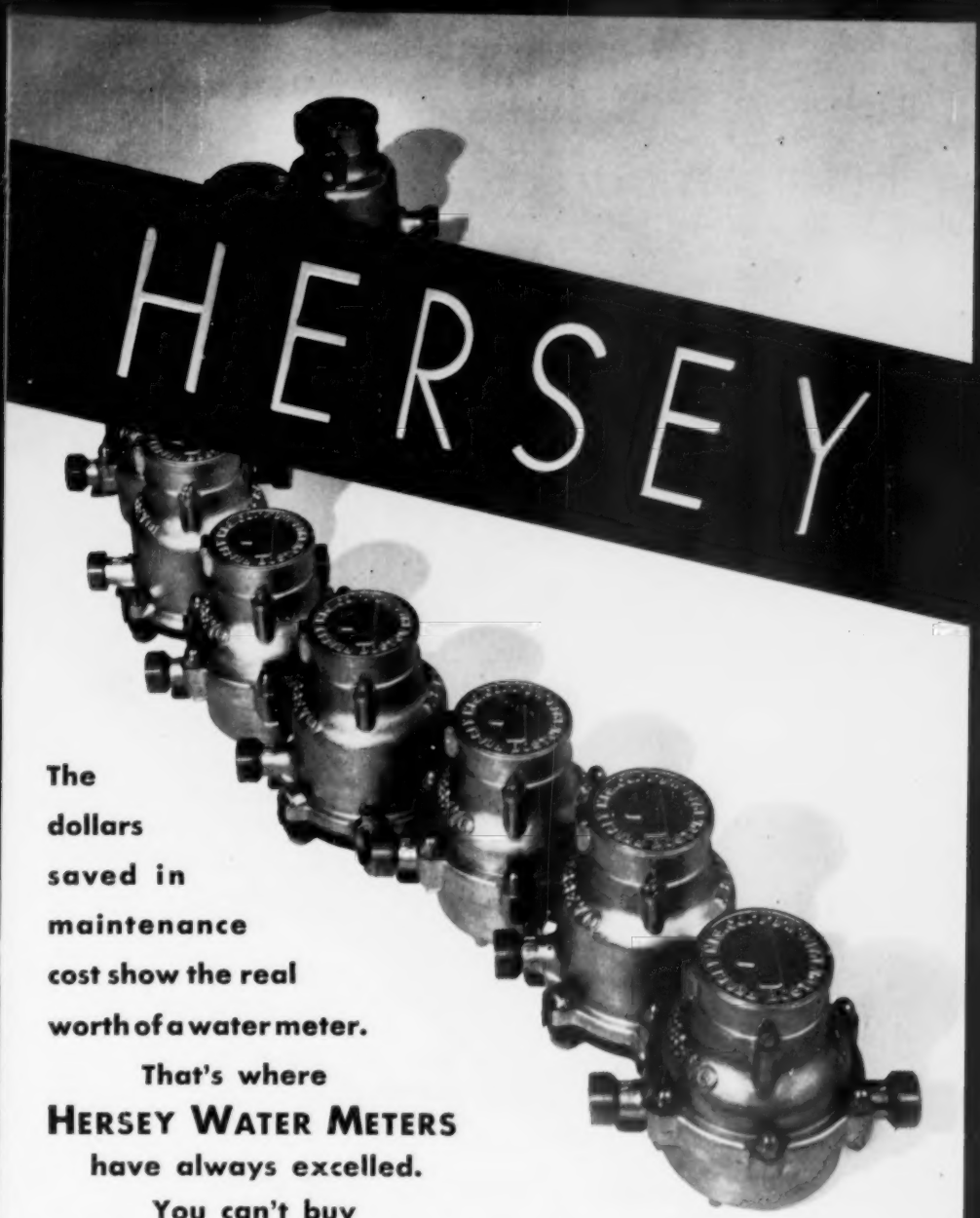

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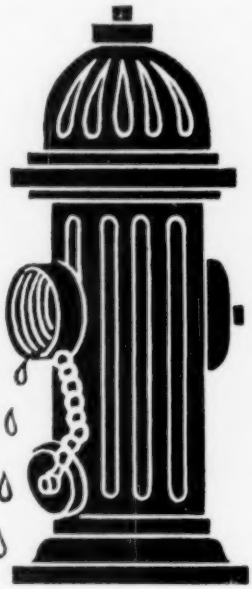

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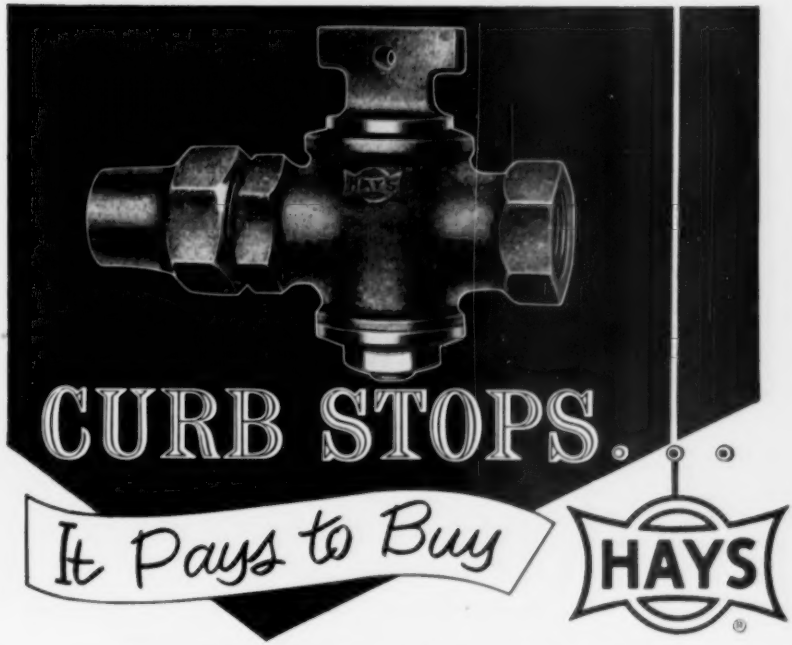

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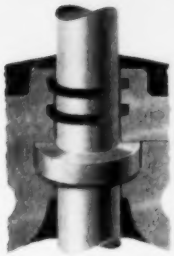

O-RING SEALS

Provide excellent seal prevent binding of stem and result in very easy valve operation. KENNEDY O-Rings are located above collar, permit repacking under pressure. Optional on KENNEDY non-rising stem A.W.W.A. valves.

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Rugged design and construction features iron that is 50% stronger than ordinary cast iron to keep KENNEDY Valves doing a better job over a longer, more dependable operating life.

KENNEDY Fig. 56
A.W.W.A. Standard Iron-Body Double-Disc Gate Valve, with Bell Ends

KENNEDY manufactures a complete line of water works valves. Sizes range from 2" to 48" including non-rising stem and outside-screw-and-yoke valves. These valves feature the hook-and-wedge type disc mechanism for easier, better and more positive valve operation. A wide variety of pipe connections are available.

For maximum service life, for the greatest value for your valve dollar, specify KENNEDY valves and fire hydrants. Remember, KENNEDY means dependability in valves, fire hydrants and accessories.

Fig. 571

Fig. 561

Fig. 566

Fig. 566G

Fig. 566FTR

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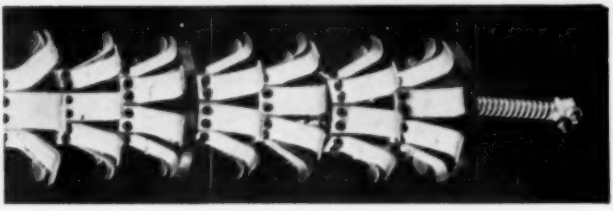

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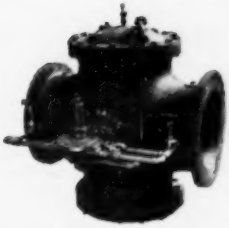


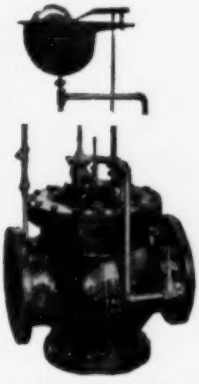
Controls elevation of water in tanks, basins and reservoirs

ALTITUDE VALVE
1. Single Acting
2. Double Acting

Maintains desired discharge regardless of change in rate of flow pressure

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



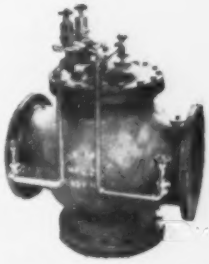
Maintains levels in tank, reservoir or basin

1. As direct acting.

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

FLOAT VALVE

A self contained unit, with controls three or more automatic



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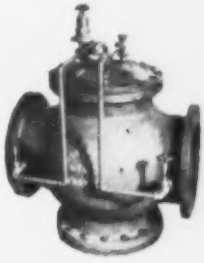
Combination automatic control both directions through the valve.

Maintains safe operating pressures for conduits, distribution and pump discharge



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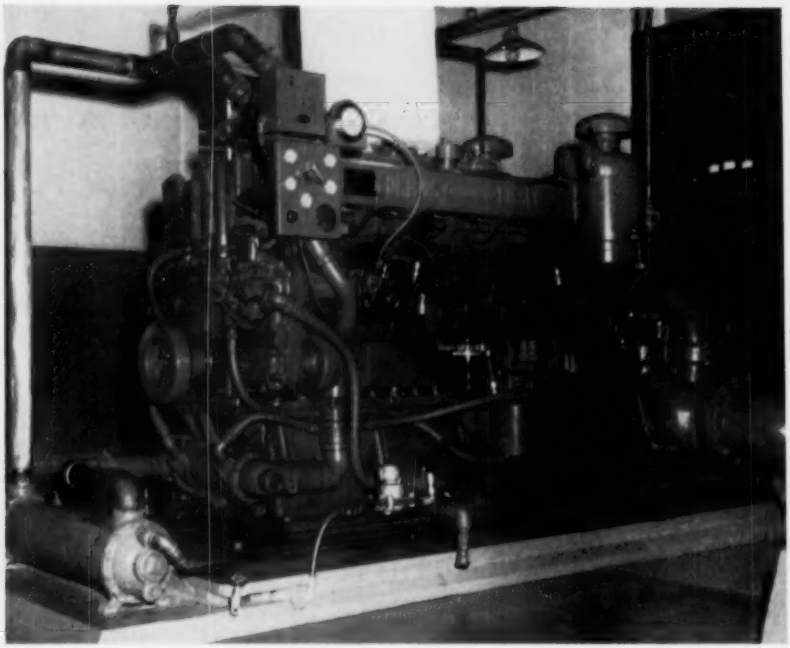

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Originally intended as a stand-by unit, this engine (rated 264 HP at 1800 RPM) has been driving a 2500 GPM high lift pump, and has handled almost the entire Summer load during 1953, 1954 and 1955. In 1954, pumping costs including depreciation came to $28 per million gallons pumped.

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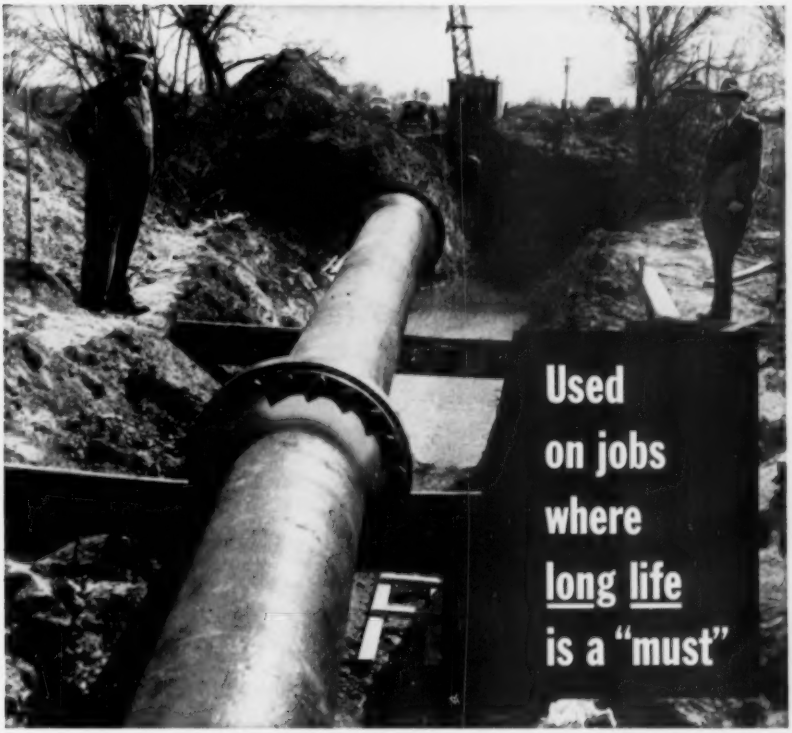
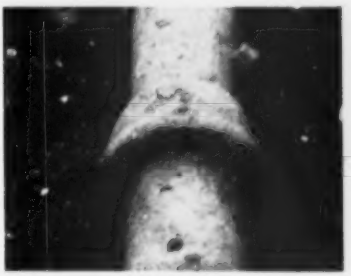


Installing cast iron mechanical joint pipe across river at Salina, Kansas, for sewer main.

When an installation, once completed, should be as trouble-proof as planning and materials can make it — engineers rely on cast iron pipe. It has high beam-strength, compressive-strength and shock-strength. Its effective resistance to corrosion ensures long life, underground or underwater. These are reasons why cast iron pipe is so widely used for water lines in tough terrain, pressure and outfall sewers, river crossings, and encased piping in sewage treatment and water filtration plants. Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, Suite 3440, Prudential Plaza, Chicago 1, Ill.



This 123-year-old cast iron water main is still in use in the distribution system of St. Louis, Mo.

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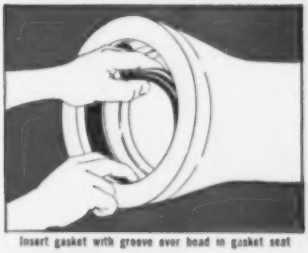
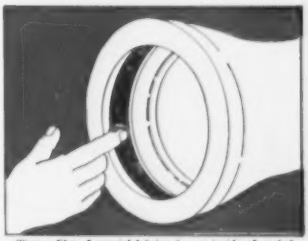
INDUSTRIAL SERVICE CAST IRON

TYTON JOINT

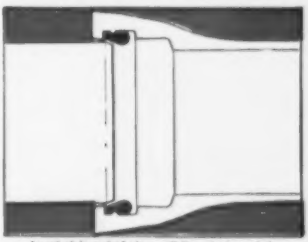
ONLY FOUR SIMPLE ACTIONS



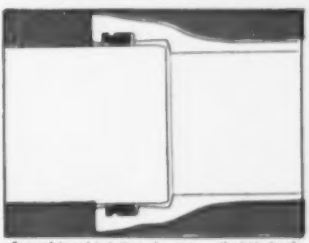
Insert gasket with groove over bead in gasket seat



Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket . . . the job's done!

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